Coal Catechism

Nicolls

Paleobotany

COAL CATECHISM

BY WILLIAM JASPER NICOLLS

◆

THE STORY OF AMERICAN COALS

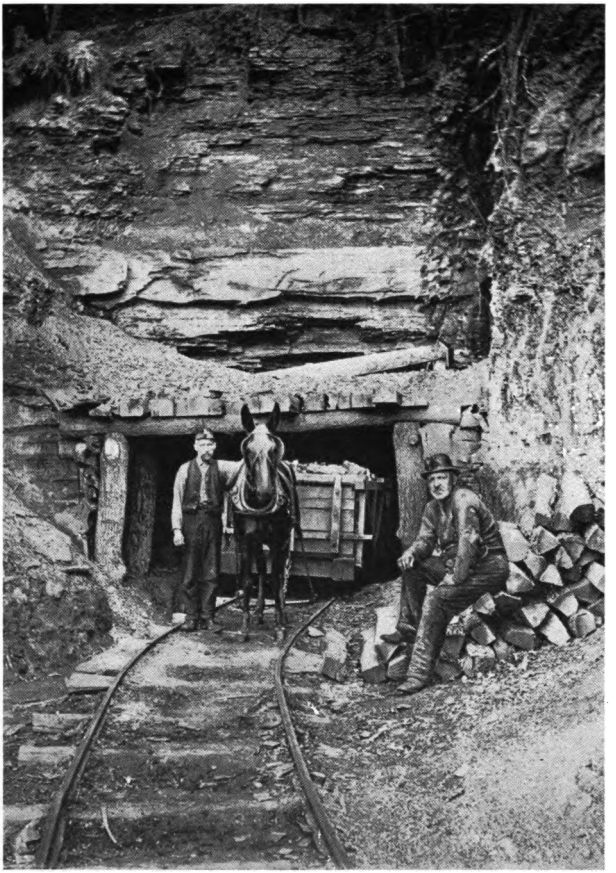
Limited to one thousand copies printed from type. 8vo. Crushed buckram, deckle edges, $3.50

THE RAILWAY BUILDER

A Hand-Book. *Fifth Edition, Revised.* 16mo. Limp, $2.00, net

COAL CATECHISM

A series of questions and answers on Coal. *First Edition.* 12mo. Buckram, $1.50



AN AMERICAN DRIFT MINE.

COAL CATECHISM

BY

WILLIAM JASPER NICOLLS
M.Am.Soc.C.E.

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY
1898

TO

J. BERTRAM LIPPINCOTT

PHILADELPHIA

"It was only the other day, so to speak, that Nature turned a creature out of her workshop, who by degrees acquired sufficient wits to make a fire, and then to discover that the black rock would burn."—PROFESSOR HUXLEY

PREFACE

CATECHISM of Coal is intended for that great number of intelligent readers who have no technical training, and yet who prefer to seek knowledge by reading special subjects rather than fiction. A large proportion of these have neither the time nor inclination to peruse the voluminous geological and statistical reports of the coal industry in the United States, or to study the ponderous volumes of gathered wisdom by technical experts. Their time is usually fully occupied with the cares of business and often with the fatigue of manual labor, and their hours for quiet reading or study are few and most precious. For these, the following plain questions and direct authoritative answers have been designed with a realizing sense of the readers' wants and aspirations. The task conscientiously assumed by the writer has been to verify all the answers by referring to competent authorities. The great number of these consulted renders it impossible to credit each one, as the result would be confusing and, in fact, impracticable, as the consensus of opinions is given and rarely

that of an individual. It is assumed that the reader knows theoretically nothing about Coal, and the questions are so arranged as to lead him gradually through the various stages of its origin, development, and uses until a full knowledge of the subject has been obtained. In justification of the catechetical form used the writer refers to the old educational catechisms used by our forefathers in many of the best universities of Europe. No better manner has since been devised for imparting a thorough knowledge of a subject, especially to those young students in our schools and colleges who desire special instruction, or to those who, from want of opportunity or otherwise, have not received the necessary training for systematic study or reading.

The writer needs no apology for his subject; its importance can scarcely be over-estimated. Coal is the basis of all energy and power, the prime mover of the wheels of industry. With Coal, we have light, strength, power, wealth, and civilization; without Coal, we have darkness, weakness, poverty, and barbarism. The most civilized nations of the world are those consuming the most Coal. At the head of these stands the United States.

W. J. N.

PHILADELPHIA, 1898.

CONTENTS

Contents

Contents

COAL CATECHISM

CHAPTER ONE

ORIGIN.

1. What is coal?

Fossil fuel; a black, earthy substance which is dug from the ground, and which can be burned for fuel.

2. Of what does coal consist?

Chemically, it consists of carbon, volatile matter, sulphur, and ash, with a small amount of water.

3. What is carbon?

Carbon is one of the most common of the elements. A diamond is pure carbon, and a piece of charcoal is carbon united with a small portion of oxygen.

4. What is meant by "volatile matter"?

The volatile matter consists of the gases,—viz., hydrogen, nitrogen, and oxygen. The combustion of these gases is seen in the flame when the coal is burning.

5. What is sulphur?

One of the simple elements. It unites with many of the metals. It is almost always to be found in coal in the form of iron pyrites, a brassy-like substance occurring in layers from the thickness of paper to half an inch.

6. What constitutes ash?

Ash is the inorganic matter of coal; the part that is not consumed in combustion. It is the earthy matter in the drift of the coal period.

7. What was the coal period?

The period of time commonly known as the Carboniferous age, during which coal was formed.

8. When was this supposed to be?

Thousands of years ago. Ages before man was created.

9. What is known of the Carboniferous age?

That it was remarkable for the luxuriant growth of vegetation of the fern variety and such plants as grow in water and swampy places. It is supposed that this mass of matted vegetation died down each year and formed into a peaty-like mass, which afterwards became coal.

10. Coal, then, was formed on the surface of the ground; how has it since been buried?

These great beds of decayed and rotting vegetation became submerged by geological changes of the earth's surface, so that the water overflowed them, carrying large quantities of sediment, which covered them over or buried them.

11. How do we account for several seams of coal, one over the other?

We suppose that vegetation again grew and flourished on the surface of the sedimentary deposit, as weeds quickly cover newly upturned soil, and that the process was then repeated.

12. If coal was formed in low, swampy places, why do we find it near the tops of mountains?

We have evidences that after the coal seams were formed the crust of the earth became disturbed by cooling, or probably by volcanic upheavals, which disturbed the continuity of the strata containing the coal seams, so that the low, flat ground was elevated and formed hills and mountains.

13. Was coal formed only in the Carboniferous age?

Coal was formed in all ages, but we do not know that any other age presented such a luxuriant growth of vegetation and under similar conditions.

14. What proof is there that coal was formed prior to the Carboniferous age?

In America we find graphite in geological strata as old as the globe itself, or what we know of it.

15. What is graphite?

In a black-lead pencil, the substance which is commonly called lead is graphite, and belongs to the carbon family. It comes next to anthracite coal.

16. Of what does the carbon family consist?

Beginning with the diamond, which is essentially pure carbon, we have next the graphite or plumbago used for stove polish, then anthracite coal, bituminous coal, lignite, and finally turf or peat, which is the youngest of the family.

17. If, then, we find graphite in the older formations, is that proof that coal also existed?

Most geologists admit that graphite represents the carbon which formed part of the woody tissue of plants that lived during those remote times, so that this mineral represents coal in the ultimate stages of carbonization.

18. Have we any other proof than the opinions of geologists?

Coal has been found converted into graphite, in the ground, by the intrusion of volcanic rock, which hastened the work of carbonization.

19. Where are some good examples of this in the United States?

In the anthracite coal mines of Rhode Island the outcrops frequently yield plumbago, and occasionally nests of almost pure graphite are found in the coal beds, which is sold as black-lead.

20. What other examples exist of pre-Carboniferous coal?

In Scotland, where coal occurs in the old red sandstone formation.

21. How do we know that coal was formed since the Carboniferous age?

Coal of post-Carboniferous age is found in Bavaria and in Germany, as also in the northern Tyrol and in Belgium and Austria.

22. Give an example of more recent formations?

Coal has been found of Miocene age in the Arctic regions of Greenland within a few degrees of the North Pole.

23. Is coal forming at the present time?

As the formation of coal has been going on in all ages, ever since vegetable life appeared, it is reasonable to suppose that in the peat bogs, delta jungles, and mangrove swamps of the present time the formation of coal for use in future ages may now be going on.

24. Give an example of probable coal formation now going on?

In the United States, at the mouth of the Mississippi River, we have the conditions required for future coal fields,—swamps, periodical inundations of water, rapid growth of weeds and vegetation, which perishes and is decomposed every winter.

25. Is coal a vegetable or mineral substance?

As before demonstrated, coal is of vegetable origin, which became mineralized on the spot where it grew, and is now found after countless years of time.

26. Why do we suppose that vegetation must have been more profuse in the Carboniferous age than now?

It has been demonstrated by figures that all the carbon contained in all our immense forests would scarcely furnish a very thin seam of coal.

27. Did it require all the forests of the Carboniferous age to form coal?

It appears not, as parts of a true forest, petrified in place, have been found in the middle of the coal itself, as well as of the sandstone near the surface of the ground.

28. Where has this occurred?

An example of this was observed in the mines of Treuil, at Saint Étienne, in France, where a standing tree was found in the position described.

29. What does this prove?

That the coal had been formed at the foot of this tree in the same way as peat, and was subsequently covered up, compressed, heated, distilled, and mineralized into fossil carbon, or coal, from other vegetation than the trees of the forest,—vegetation of rank and luxuriant growth.

30. Was the Carboniferous or coal period of long duration?

Under such favorable conditions it seems probable that the Carboniferous age need not have been of long duration. At that time the common horsetails and club-mosses of the present day grew as large as our trees.

31. How do we know that?

By the impressions of the plants and flora which are found in the rock strata. These impressions were originally made in the soft sandy material, which afterwards hardened.

32. What are these impressions called?

They are called fossiliferous flora and organic remains.

33. Are these fossiliferous flora found in the coal?

Occasionally small portions of leaves, stems, and the structure of woody fibre are found in the coal itself, and the microscope reveals the presence of organic remains.

34. Are these sufficiently numerous to prove that coal is of vegetable origin?

In the coal itself we find little proof of its origin, owing to the chemical and mechanical changes which have occurred in the original deposit.

35. Where do we get the evidence—from organic remains?

In the interstratified clays, shales, and other deposits we find plant remains in every state of preservation,—from delicate ferns to the trunks of trees. These prove the vegetable origin of coal.

36. Are these fossil remains petrifications or casts and moulds of the original flora?

The impressions of vegetation occur in four different conditions. Some consist of vegetables converted into carbonaceous clay, and still invested with their bark reduced to charcoal. Others exhibit impressions of the same plant with the surface entire upon clay, slate, or sandstone. Others are decorticated (barked or husked) vegetables themselves, and, lastly, others are impressions of these decorticated plants.

37. Name some of the fossiliferous flora?

Among the most common varieties of vegetable remains are the following: Sphenopteris, sigillarea, lepidodendron, neuropteris, asterophyllites, and calamites.

38. Describe the sphenopteris?

The sphenopteris is similar in appearance to a fern, with branching, beautifully formed leaves, their veins radiating from the base of the stem.

39. Is the sigillaria an important species of Carboniferous flora?

Probably more so than any other; a great deal of the coal seems to have been formed of this

tree, which measured from 3 to 5 feet in diameter. The impressions of the sigillaria are beautifully symmetrical, as though made by a seal in the soft wax.

40. What is remarkable in the lepidodendron?

The trees of the lepidodendron are known to have attained a growth of from 40 to 50 feet, which is remarkable when we consider that they belong to the variety now called club-mosses, the largest tropical variety of which does not now attain a height of more than 3 feet.

41. Describe the neuropteris?

The neuropteris is of the fern variety, and has a broad leaf somewhat like a heart in shape.

42. What is peculiar of the asterophyllites?

The asterophyllites are characterized by the graceful arrangement of the leaflets in the form of stars, radiating from a central stem.

43. To what plant has the calamites been compared?

To the bamboo and *equiseta*, or common "horse-tails." They seem to have grown in dense jungles or brakes.

44. What remarkable circumstance is manifested in coal vegetation?

Its uniform appearance over the greater portion of the globe. The plants of the coal age are alike in Europe, America, Australia, and regions approaching the North Pole.

45. What do we argue from this circumstance?

That the climate of the globe must have been nearly the same in these far distant points at that period of the world's history.

46. What kind of a climate must it have been?

It must have been a warm climate with an abundance of moisture or humidity. It is also probable that the percentage of carbonic acid in the atmosphere was much larger than now in order to account for the inordinately luxuriant growth of the plants which make up the fossil fuel. This climate would not have supported human life.

CHAPTER TWO

GEOLOGY.

47. What is geology?

Geology is an inquiry into the history and development of the earth's crust and of the several floras and faunas which have dotted and peopled its surface.

48. What are geological systems?

They are the different periods in the world's history which are distinguished from each other by rock strata containing similar fossils or organic remains.

49. What is the oldest system?

The Archæan.

50. How many systems are there?

Fifteen in all, as follows: Archæan, Cambrian, Silurian, Devonian, Carboniferous, Permean, Triassic, Jurassic, Cretaceous, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Recent.

51. In what system do we find the coal and coal fossils?

In the Carboniferous principally, but they have also been found in several of the others.

52. Do we find any proof of human life in the fossils of the Carboniferous system?

None whatever; all scientists agree that no human being existed in that period of the world's history.

53. Have we evidence of any living things?

The coal measures contain fossils and casts or impressions of centipedes, spiders, lizards, scorpions, crabs, and lobsters, also an insect resembling a cockroach. Many remains have been found of the mollusca, or shell-bearing animals, and also of fishes,—many of great size. The air was probably at that period full of innumerable millions of infusoria infesting the swampy land.

54. How were the coal basins formed in America?

It is supposed that at one time vast seas swept over the land, excepting the elevated mountainous districts, which contained active volcanoes. The action of the waters rounded the fragments of volcanic rock and washed them into great basins of conglomerate rock and sandstone.

55. How were these basins filled with coal?

Upon these beds or basins was accumulated the vegetable matter which, rotting and settling for ages, became coal.

56. In what part of the world are these coal basins found?

Principally in the United States, Great Britain, Germany, France, Austria, Belgium, Russia, Canada, Japan, Spain, New Zealand, Sweden, and Italy.

57. Which of the foregoing countries contains the largest coal basins?

The United States and Great Britain contain, in area, more than all the others combined.

58. How many principal coal basins are in the United States?

There are six distinct basins.

59. Locate the largest basin?

It extends west from the Allegheny Mountains to the Missouri River, a distance of about 1500 miles, and south from the lakes to the mouth of the Ohio River, about 600 miles.

60. How does this coal basin compare with those in Europe?

It is larger than any other known basin in the world. It would cover half of Europe, having an area of 900,000 square miles.

61. In how many States of the Union is coal found?

Twenty-eight States are now included in the coal producers.

62. Name them?

The coal-producing States include Alabama, Arkansas, California, Colorado, Georgia, Illinois, Indiana, Indian Territory, Iowa, Kansas, Kentucky, Maryland, Michigan, Missouri, Montana, New Mexico, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, and Wyoming.

63. Were the coal basins once filled with water?

We suppose these great basins to have been, at one time, the beds of vast inland lakes or seas.

64. What proof have we that such was once the case?

Geologists trace the movements of vast bodies of water from the interior to the oceans. They point

to the gaps and breaks in the great mountain ranges, traversing America from northeast to southwest, as the probable points through which these lakes burst and were emptied into the sea.

65. What familiar example have we in evidence of these movements?

The Delaware Water Gap, as viewed from the summit of Mount Pocono. Here the mountains resemble the breast of a great dam, and the Gap shows the break through which the pent-up waters rushed forth to the sea.

66. Is it possible that any of our present lakes might burst their barriers?

It has been suggested that Lake Erie might eventually be drained by the retrograde movement of Niagara Falls, which is gradually wearing away the restraining rock which holds back the lake.

67. What progress has already been made?

Niagara Falls has already receded some 7 or 8 miles.

68. At this rate how long would it take to reach the lake?

The rate of progress has been calculated at about one foot in a year. This rate being continued, it

would take about 132,000 years, the distance being something less than 25 miles.

69. Into how many periods are the geological systems divided?

Into four periods,—viz., Eozoic, Palæozoic, Mesozoic, and Neozoic.

70. In which period is the Carboniferous or coal system?

It is the second or Palæozoic period of time.

71. How is coal usually found?

Coal is found in beds or seams, ranging in thickness from an inch to 30 feet, and covering wide tracts of land.

72. What are the "coal measures"?

Under that name are included all the various strata of rock occurring during the period of the coal formation.

73. How are the coal-beds separated?

They are separated from each other by beds of sandstone and compressed clay or shale.

74. Are these coal-beds always continuous?

Very often the coal occurs in groups of several beds separated from each other by strata known as "barren measures" of considerable thickness.

75. What is the "underclay"?

The underclay is the bed below the coal-seam. It is a sort of fossil soil, filled with roots and rootlets, on which rests the coal.

76. What is the physical structure of coal?

Coal consists of successive thin layers of hard coal, sometimes bright and then dull, interspersed at irregular intervals with a dusty, fibrous substance, like charcoal, known as "mother coal." These alternate with thin partings or layers of dark shale or slate, upon which are usually present marks and impressions of the stems and leaves of plants.

77. Of what does the "roof" consist?

Above the coal is its roof of hardened clay or sandstone, and this generally contains many remains of plants and trees, also fossil stumps of trees.

78. What are these fossil stumps called?

In some places they are known to the coal-miners as "coal-pipes," and are dreaded by them in consequence of the accidents which occur from their suddenly falling after the coal which supported them has been removed.

79. What remarkable event in the world's history occurred in the Carboniferous period?

The introduction into our world of the earliest known vertebrate animals, which could open their nostrils and literally "breathe the breath of life."

80. How had all previous animals lived?

All previous animals, except a few insects, had respired in the water by means of gills or similar apparatus.

CHAPTER THREE

HISTORY.

81. What is history?

History is a continuous narrative of events; a chronicle or register of happenings in the order of time; a record.

82. When does the history of coal begin?

The history of coal begins properly with the first mention which we can find of it in written or printed narrative.

83. What is the earliest mention made of coal?

The first mention made of coal is contained in the Bible, Prov. xxvi. 21,—"As *coals* are to burning *coals* and wood to fire, so is a contentious man to kindle strife."

84. When and by whom was this written?

It was written by King Solomon about the year 1016 B.C., and is supposed by many authorities to refer to charcoal.

85. Was not Solomon familiar with coal?

King Solomon's empire contained Syria, which abounds in coal, fossils, and bituminous pits, and

it is reasonable to suppose that the coal which is now found in the rocks about Hermon and Lebanon was not unknown to the Jewish king.

86. What is bitumen?

Generally speaking, bitumen is a mineral oil combined with other various substances.

87. What are some of the properties of bitumen?

Among the properties of bitumen we have naphtha, petroleum, mineral tar, and asphalt. Coal is also supposed to contain some bitumen.

88. Where is the next mention of coal in the Bible?

The next is contained in Isaiah xlvii. 14,—"There shall not be *coal* to warm at."

89. When was this written?

This was written about 750 B.C. and probably 100 years before the next biblical mention of coal, which occurs in Lamentations iv. 8,—"Their visage is blacker than a *coal*."

90. Have we any mention of coal in ancient times besides those made in the Bible?

A description of coal occurs in the writings of Theophrastus.

91. Who was Theophrastus?

Theophrastus was a Greek orator and philosopher, and a friend of Aristotle.

92. How did he describe coal?

He wrote: "Those substances that are called coals and are broken for use are earthy, but they kindle and burn like wooden coals."

93. Where did he say they were to be found?

He described them as occurring in "Lyguria, and in Elis, over in the mountains towards Olympias."

94. How long ago was this written?

About 2200 years ago, or over 300 years before Christ. This is the first mention of coal made by other than sacred writers.

95. Have we any mention of coal in the New Testament?

The word "coals" is used by John the Apostle in his Gospel, 18th chapter and 18th verse,—"And the servants and officers stood there, who had made a fire of *coals*, for it was cold."

96. When was this written?

Probably about the year 60 A.D.

97. Have we any present evidences of coal being used in ancient times?

On several occasions tools and cinders have been found in England near the ancient Roman wall, which seem to prove that the Britons used coal prior to 54 B.C., or the time of the Roman invasion.

98. What is the first actual record of the use of coal in England?

The first record is in the form of a receipt, which was given by the Abbey of Petersboro in 852 A.D. for "twelve cartloads of coal." The first record of actual mining operations is contained in the books of the Bishop of Durham in the year 1180.

99. Did the use of coal then become general?

The use of coal must have been very gradual, for more than a hundred years later a Venetian traveller wrote to his countrymen about "a kind of black stone used like firewood," and they did not believe him.

100. When was the first shipment of coal made to London?

In the year 1240, but it was not until nearly 400 years later when the discovery was made

that coal could be used in a blast-furnace for smelting iron ore.

101. When was coal first discovered in America?

The first discovery of coal in America was made in 1679 by Father Hennepin, a French Jesuit missionary. In his journal he notes the traces of bituminous coal above Fort Crecolier, on the Illinois River, near the present town of Ottawa.

102. When was coal first mined in America?

Coal was first mined in America in 1750 in the Virginia bituminous coal fields, which were opened and worked on the James River, near Richmond.

103. Was this an American enterprise?

The Virginia mines were owned and operated by an English company, who for some time enjoyed the exclusive coastwise trade of the United States.

104. Was this trade very large?

Not much coal was produced at first. The output was so expensively mined and the cost so great that few individuals used it in the coast cities, but burned wood instead.

105. Are the mines still in operation?

Small operations are still carried on at the Gay-

ton mines in Henrico County and the Midlothian mines in Chesterfield County, near Richmond, Virginia.

106. What peculiar features do these Virginia coal fields possess?

With one exception they are the only coal fields in the United States which are situated at or near the Atlantic seaboard.

107. Where are the other Atlantic seaboard mines located?

In the State of Rhode Island.

108. What is the nature of the coal found there?

In Rhode Island is found a hard anthracite coal, with occasional beds of plumbago, and pure graphite, commonly known as black-lead.

109. Are the Rhode Island mines in operation?

Many efforts have been made to work these coals in competition with the great Pennsylvania coal-beds, but practically without success. They are not now in operation.

110. When was anthracite coal first discovered in America?

Anthracite coal was first discovered in Rhode

Island in 1760. In 1766 it was first found in the Wyoming Valley, in Pennsylvania, by James Tilghman, of Philadelphia, who sent a small sample of it to William Penn, in London. It was known in 1770 that anthracite coal could be had near the towns of Mahanoy and Shamokin, in Pennsylvania, and in 1790 its presence was discovered near Mauch Chunk, in the Lehigh region of Pennsylvania.

111. When was the first shipment of anthracite coal made in the United States?

During the Revolutionary War, in 1776, coal was taken to Carlisle for the United States army. It was taken to Harrisburg, the present capital of Pennsylvania, in boats, or arks, and from there hauled in wagons to Carlisle.

112. What other shipment was made by wagon?

In 1800 William Morris took a wagon-load of anthracite coal from Tamaqua to Philadelphia, a distance of nearly 100 miles, but was unable to sell it.

113. Why could he not sell it?

The coal could not be made to burn, and was condemned as nothing but "black stones" and unfit for use.

114. How was coal first shipped by water?

It was loaded on rudely constructed boats called "arks" and floated down the rivers, in the direction of the current, to its destination.

115. What were these arks like?

They were made of rough timbers, about 90 feet long by 16 feet wide and 4 feet in depth. Each end terminated in a sharp point, with a single oar, some 30 feet long, requiring two men to work it. It usually took four men seven days to navigate an ark from the anthracite mines of Pennsylvania to the Atlantic seaboard, the cost of the trip being about $50.

116. How much did an ark cost?

The total cost of an ark was $70, and as it could not be brought back up stream or against the current it had to be sold with the coal for about $15.

117. What was the cost of transporting coal by this system?

About $5.00 per ton.

118. How does this price compare with the present price of transportation by railroads?

It was nearly five times greater.

119. At what price was anthracite coal sold in those days?

Anthracite coal was sold in Philadelphia and Baltimore at from $10 to $12 per ton.

120. What was the capacity of an ark?

An ark held about 60 tons of run-of-mine coal.

121. What is meant by "run-of-mine" coal?

Coal as it is dug in the mines, lump and fine coal all together, without any preparation or screening, is called run of mine.

122. When was the first ark-load of Clearfield semi-bituminous coal shipped?

In 1804 William Boyd shipped the first ark-load of Clearfield coal down the Susquehanna River to Columbia, in Pennsylvania, a distance of about 260 miles. This was followed by other shipments at irregular intervals.

123. Was this system of transportation a safe and easy one?

On the contrary, it was very dangerous and risky, on account of the rapid currents and submerged rocks in the beds of the rivers.

124. What proportion of accidents occurred to these coal arks?

Only two-thirds of the arks which started down the rivers ever reached their destination, one-third generally going to pieces on the bars and rocks.

125. What other attempt of transporting coal by wagons followed that of Mr. Morris?

An attempt was made in 1812 by Colonel George Shoemaker, of Pottsville, to haul coal by wagons and horses to Philadelphia. He succeeded in delivering nine wagon-loads of anthracite.

126. Was his venture a success?

The public were not familiar with "hard coal," having used nothing but bituminous, and Colonel Shoemaker was regarded as an impostor for attempting to sell "black stones" as coal. He had some difficulty in getting out of the city to avoid arrest!

127. What became of the nine wagon-loads of anthracite coal?

Of the nine, two loads were sold, and the other seven loads he gave away.

128. How was it ascertained that Colonel Shoemaker's coal would burn?

A whole night was spent in the effort to make the coal burn, when the men quit their work in despair, but left the furnace door shut. One of the workmen returning some time afterwards found everything red-hot.

129. When was the first cargo of anthracite coal shipped "outside the Capes"?

In 1823 the first cargo of anthracite coal was shipped around Cape Cod by vessel, consigned to the Boston Iron Works.

130. When was the first shipment of bituminous coal made from a Pennsylvania mine to the seaboard?

In 1828 an ark-load of bituminous coal from Karthaus, in Clearfield County, Pennsylvania, was taken down the Susquehanna River to Port Deposit, at the head of Chesapeake Bay, and was then reloaded into a sailing vessel and carried to Philadelphia.

131. When was the first shipment of bituminous coal made from a Maryland mine to the seaboard?

In 1842 the first shipment of bituminous coal from the Cumberland region, in Maryland, was

made by railroad to Baltimore, over the Baltimore and Ohio Railroad.

132. What was the cost of transporting anthracite coal by wagons and horses to Philadelphia?

From $25 to $30 per ton, which was so great as to make it impracticable.

133. What other systems of transportation came into use?

The introduction of steam power, at about the year 1812, rendered some of our rivers navigable up stream as well as down, and about this time the construction of canals was begun in various States, notably in Pennsylvania, Maryland, and Virginia.

134. What is the first recorded movement of coal "by rail"?

In 1812, at Leeds, in England, an engine, made by Blenkinsop, hauled 33 coal-wagons, on a railroad, at a speed of 3¾ miles per hour.

135. When was the first attempt made to haul coal with locomotives in the United States?

In 1829 the first application of steam to coal transportation was made by Horatio Allen, at Honesdale, for the Delaware and Hudson Canal Company. His locomotive, called the "Stourbridge

Lion," and weighing seven tons, was imported from England. It ran at a speed of 10 miles per hour.

136. How many miles of railroad were in operation in the United States in the year 1830?

About 40 miles altogether.

137. How many miles are now in operation?

Over 181,000 miles, or six times that of any other country in the world.

138. Who invented the railroad?

To the coal operators in the North of England is unquestionably due the invention of the railroad.

139. Why is the invention due to them?

They first contrived the double parallel line of rails fixed to the ground and furnished with flanges to prevent the wheels of the wagons from slipping aside when hauling coal.

140. What were these contrivances called?

These early railroads were called "tramways," and they are the origin of all the rail transportation systems in the world.

CHAPTER FOUR

GEOGRAPHY.

141. How do the American coal fields compare with the transatlantic fields?

In area the American coal fields rank first of all known coal fields in the world.

142. How do they compare with those of Great Britain?

The American fields are 37 times greater than the coal fields of Great Britain, according to estimates made by Professor Jevons, an eminent English scientist.

143. What is meant by "the geography of American coals"?

The geography of American coals is a description of the coal fields of America and their locations.

144. Which State is the most important of the coal-producers?

Pennsylvania is the largest coal-producing State in the Union.

145. Which is the most important coal field in the United States?

The anthracite regions of Pennsylvania are of the first importance in the American coal fields.

146. Where are they located?

Geographically the anthracite fields are located about the middle of the eastern portion of the State, and include the counties of Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, and Dauphin.

147. What is the area of this field?

The anthracite regions of Pennsylvania are comparatively small, embracing only about 480 square miles.

148. How much did the Proprietary Government pay for this strip of coal land?

It was purchased for £500, or, in American money, about $2500.

149. Did the purchase prove to be a profitable investment?

From that investment we have realized nearly $4,000,000,000—the value of the coal mined at tidewater—since operations first began.

150. Are there any other anthracite coal fields in the United States?

There are some fields of anthracite coal in Colorado, New Mexico, and Virginia, but they are small, and thus far have not produced much coal.

151. How are the anthracite coal fields of Pennsylvania divided?

For trade purposes they are divided into three regions,—viz., the Wyoming, Schuylkill, and Lehigh.

152. Of the three regions named, which is the most important?

The Wyoming region is by far the most important, producing, as it does, over 50 per cent. of the entire output of anthracite coal.

153. Which region is the next in importance?

The next in size and production is the Schuylkill region, with 35 per cent. of the entire output, while the Lehigh region comes last with the remaining 15 per cent. of production.

154. Where are the anthracite fields of Colorado situated?

In Colorado the only anthracite coal mined comes from the Grand River field, in the extreme western

part of the State, which includes the counties of Rio Blanco, Garfield, Mesa, Delta, Pitkin, and Gunnison.

155. Where are the anthracite fields of New Mexico situated?

In New Mexico the anthracite territory is in Santa Fé County.

156. What curious coal formation here occurs?

In some parts of New Mexico both anthracite and bituminous coal occur in the same mines.

157. What is the cause of this occurrence?

It is supposed that the heat of the porphyritic rock which here penetrates the coal measures caused the transformation of bituminous coal into anthracite.

158. How do the bituminous coal fields of the United States compare in area with the anthracite?

The territory in which bituminous coal is found in the United States is more than 400 times as extensive as the anthracite fields.

159. How are the bituminous coal fields of the United States divided?

They are divided into seven regions, as follows: The Triassic, Appalachian, Northern, Central, Western, Rocky Mountain, and Pacific coast.

160. Which of these divisions is the most important?

The Appalachian region is the most important of the seven great bituminous divisions of the United States.

161. Where is it situated?

It extends from the northern part of Pennsylvania in a southwesterly direction, following the great Appalachian chain of mountains, to the central part of Alabama.

162. What is the area of this field?

Its area is about 62,690 square miles, covering nearly all of Western Pennsylvania, the southeastern part of Ohio, the western part of Maryland, the southwestern corner of Virginia, nearly all of West Virginia, the eastern part of Kentucky, a portion of Eastern Tennessee, the northwestern corner of Georgia, and nearly all Northern Alabama.

163. What is the length and breadth of the Appalachian bituminous field?

Its length is a little over 900 miles, and it ranges in width from 30 to 180 miles.

164. Which is the next in importance of the seven grand divisions of the bituminous coal fields?

The second region in importance and producing capacity is the Central field, which includes all of

Indiana and Illinois and the western part of Kentucky, with an area of 47,850 square miles.

165. Which is the third bituminous field in importance and product?

The Western region, embracing all the coal areas west of the Mississippi River, south of the forty-third parallel, and east of the Rocky Mountains, including Iowa, Missouri, Nebraska, Kansas, Arkansas, Texas, and Indian Territory, in area about 25,000 square miles.

166. What does the Rocky Mountain bituminous field include?

The Rocky Mountain region includes the coal areas contained in Colorado, Idaho, Montana, New Mexico, North Dakota, Utah, and Wyoming, estimated at about 25,000 square miles.

167. What does the Pacific coast field embrace?

The Pacific coast field embraces all the bituminous areas in the three States bordering on the Pacific Ocean,—California, Oregon, and Washington. Of the three States included in this field, Washington comes first in the quantity of coal produced, Oregon next, and California last. The coal-producing area has been estimated at 10,000 square miles.

168. Where is the Northern field?

This is altogether in the State of Michigan, covering an area of 6700 square miles, and including nearly all the central part of the State.

169. Where are the principal operations in the Northern field?

The principal operations are carried on near the city of Jackson, in Jackson County, Michigan.

170. What does the Triassic region comprise?

The Triassic region comprises what is known as the Richmond basin, in Chesterfield and Henrico Counties, Virginia, and the Deep River and Dan River fields in North Carolina.

171. What is peculiar in the coal formations of this region?

As the name indicates, the coal formations here are of the Triassic geological period, or more recent than those of the Carboniferous age. Here also is found coal which in its formation differs materially from all other coal formations in this country, and which is perhaps the oldest coal in existence, or the first creations of the Carboniferous age.

172. Which State in the Union produces the greatest amount of bituminous coal?

Pennsylvania, which produces each year as much bituminous coal as it does anthracite.

173. In which State does the great Appalachian coal field cover the most area?

In West Virginia the total coal area embraces about 16,000 square miles, or 60 per cent. more than Pennsylvania, and more than 80 per cent. of the total bituminous area of Pennsylvania and Ohio combined.

174. Which is the second State in importance of the coal-producers?

Illinois ranks second in coal production, but is first in coal area, which is about four times as large as the bituminous areas in Pennsylvania, more than twice as large as that of West Virginia, and more than half as large as the entire Appalachian coal field.

175. How does Ohio rank amongst the coal-producing States?

Ohio ranks the third in importance amongst the coal-producing States, having a bituminous area of about 12,000 square miles.

176. Which are the principal bituminous coal-producing States in the Union?

These four States: Pennsylvania, Illinois, Ohio, and West Virginia. Together they produce more than twice as much coal as all of the other States combined.

177. What is the total area of the bituminous coal fields in the United States?

In some parts of the Western, Rocky Mountain, and Pacific coast fields the areas are as yet unknown, but the latest developments show a bituminous area of nearly 200,000 square miles.

CHAPTER FIVE

PRODUCTION.

178. What is the coal production of the United States?

The total output from the coal mines of the United States was about 192,000,000 tons, of 2000 pounds to each ton, for the year 1896.

179. What does this include?

This includes all the coal sent to market, either by shipment from the mines to distant points, that which is sold locally, and also the coal consumed by the mine employés and by the mine operators in locomotives, under stationary boilers, etc., in working the mines, and technically known as "colliery consumption." It also includes the coal manufactured into coke.

180. How much coal is used in colliery consumption and locally near the mines?

About 7,000,000 tons, of 2000 pounds each, are used annually for colliery consumption, and 9,500,000 for local trade.

181. How much of this annual production is anthracite coal?

The annual production of Pennsylvania anthracite coal, which practically includes all the anthracite coal produced in the United States, is about 54,000,000 tons of 2000 pounds.

182. What is the value of this coal?

The value of Pennsylvania anthracite coal in 1896 was $81,000,000, or an average of $1.50 per ton of 2000 pounds at the mines.

183. How many men are employed in producing the Pennsylvania anthracite coal?

The number of men employed in the anthracite mines is about 149,000.

184. How many days in the year 1896 were these men employed?

In 1896 the anthracite miners averaged only 174 working days, or about two-thirds of the time.

185. Of the total production of anthracite coal, how much was mined outside of Pennsylvania?

Only 67,000 tons of 2000 pounds each, which was mined in Colorado and New Mexico.

186. What is the total production of bituminous coal in the United States?

The total production of bituminous coal is about 138,000,000 tons of 2000 pounds each annually.

187. What does this embrace?

It embraces all the bituminous, semi-bituminous, gas-coals, cannel, block, lignite, and brown coals.

188. What is the value of this coal?

The value of the total bituminous production of the United States in 1896 was about $114,800,000, or an average of about 83 cents per ton of 2000 pounds, at the mines.

189. How many men were employed in producing this coal?

The number of men employed in producing the bituminous tonnage in 1896 was about 237,000.

190. How many days in the year were these men employed?

The bituminous miners averaged only 192 working days, or about two-thirds of their time.

191. Which is the most important of the coal-producing States?

Pennsylvania comes first, with about 37 per cent. of the total bituminous product; but including her

anthracite product Pennsylvania produces 57 per cent. of the total coal output.

192. Which State is the second in the production of coal?

Illinois comes second, with 13 per cent. of the bituminous product and 9 per cent. of the total coal output.

193. Which State is the third in coal production?

Ohio is the third in production, with 10 per cent. of the bituminous output and 7 per cent. of the total.

194. Which State is the fourth in importance of the coal-producers?

West Virginia is the fourth in production, with 10.5 per cent. of the bituminous output and 6.9 per cent. of the total tonnage of the United States. In 1873 the entire coal product of West Virginia was only 672,000 tons; to-day this has increased to about 12,800,000 tons annually.

195. Name the other coal-producing States as they rank in production?

Alabama is the fifth State in the production of coal; then comes Iowa, Indiana, Maryland, Kentucky, Colorado, Kansas, Tennessee, Missouri,

Wyoming, Montana, Virginia, Indian Territory, Washington, Arkansas, New Mexico, Texas, Utah, Georgia, and Michigan in the order named.

196. Is any coal produced outside of these States?

A small annual production comes from other States than those named, but the total amount is comparatively small.

197. What is the average production of anthracite coal per man per working day in the United States?

The average number of tons produced per working day by each man employed in all capacities in the anthracite fields of the United States is shown by statistics to be about two net tons.

198. What is the average production of bituminous coal per man per working day in the United States?

The average number of tons produced per working day by each man employed in the bituminous fields of the United States is shown by statistics to average about three net tons.

199. How much of the coal production of the United States is manufactured into coke?

Of the total coal production of the United States about 16,000,000 tons is manufactured into coke.

200. In what year was anthracite coal first produced in Pennsylvania and what was the total tonnage?

In 1820 the total anthracite production of Pennsylvania was 365 tons, which was shipped from the Lehigh region.

201. Where is the coal production of the United States sold?

Almost the entire production of American coal is sold and consumed at home, although a small percentage is exported to other countries, principally by rail over the international bridges and by lake and sea to the Canadian provinces.

202. What other exports of American coal are made by sea?

Other small tonnages are exported by sea to the West Indies, to Central and South America, and elsewhere.

203. What is the total amount of these exports annually?

The total amount of coal exported annually from the United States to other countries is now about 3,500,000 tons.

204. Are there any imports of coal made from foreign countries to the United States?

A small amount of coal is added to the production in the United States by imports, principally from Australia and British Columbia to San Francisco, from Great Britain to the Atlantic and Pacific coasts, and from Nova Scotia to Atlantic coast points.

205. What is the total amount of these imports annually?

The total amount of foreign coal imported annually to the United States is now about 1,200,000 tons.

206. Is there any duty or tariff on these imported coals?

The United States Government has had a tariff on imported coals since 1824, excepting on anthracite coal, which has been free of duty since 1870, and on coal from the British possessions in North America, which under the reciprocity treaty was admitted free of duty during the period from June, 1854, to March, 1866.

207. How has the tariff on imported coals varied since 1824?

From 1824 to 1843 the tariff was $1.68 per long ton (2240 pounds).

From 1843 to 1846 the tariff was $1.75 per long ton.

From 1846 to 1857, 30 per cent. ad valorem was charged.

From 1857 to 1861, 24 per cent. ad valorem on all foreign coals.

During 1861 bituminous and shale paid $1.00 and all others 50 cents per ton.

From 1862 to 1864, bituminous and shale, $1.10 per ton; all others, 60 cents per ton.

From 1864 to 1872, bituminous and shale, $1.25 per ton; all others, 40 cents per ton.

From 1872 to 1894, bituminous and shale, 75 cents per ton; slack or culm, 40 cents.

From 1894 to 1897, bituminous and shale, 40 cents per ton; slack or culm, 15 cents.

208. What is the present duty on imported coal?

By act of Congress, approved July 24, 1897, the duty on imported coal was fixed at 67 cents per long ton "on all coals containing less than 92 per cent. of fixed carbon and shale;" and on coal slack or culm passed through a half-inch screen, 15 cents per long ton.

209. How much coal is produced annually in the world?

The total production of coal in the world is something over 660,000,000 tons each year.

210. Which is the greatest coal-producing country in the world?

At the head of all coal-producing countries is Great Britain, with an annual tonnage of over 218,000 000 net tons.

211. Which country ranks second in coal production?

The United States is the second in tonnage with 192,000,000 tons annually, but must soon rank as first.

212. Why must the United States soon rank as first in coal production?

Owing to the vast extent of American coal fields and the cheapness of production. New coal regions are constantly being developed, while the smaller fields of the old world, circumscribed and long worked, are becoming more expensive in operation each year.

213. Which country ranks third in coal production?

Germany is the third in tonnage of the coal-producing countries, having an annual output of nearly 124,000,000 tons.

214. Which country ranks fourth in tonnage?

Austria-Hungary produces nearly 36,000,000 tons of coal annually, and ranks as fourth in tonnage.

215. Name the fifth in rank of the coal-producing countries?

France ranks as the fifth in importance of the world's coal-producers with 32,000,000 tons annually.

216. Give the names of the other coal-producing countries with their relative importance and annual tonnage?

Belgium ranks as sixth with over 23,000,000 tons of coal annually; Russia as seventh with 10,000,000 tons; Canada as eighth with less than 4,000,000 tons; Japan, India, New South Wales, and Spain each also producing less than 4,000,000 tons of coal annually; and New Zealand, Sweden, Italy, Transvaal, Queensland, Victoria, Natal, Cape Colony, and Tasmania with tonnages ranging from 1,000,000 to 40,000 tons each year.

217. What percentage of the whole world's coal production is mined in the United States?

About 30 per cent. of all the world's coal is produced in the United States.

CHAPTER SIX

CLASSIFICATION.

218. How do we classify coal?

In the family of the carbons, which varies in composition from the fattest or most highly volatile and bituminous substance to the leanest and least combustible.

219. How are the American coals classed?

American coals are divided into two kinds,—namely, anthracite and bituminous. These are again subdivided into many varieties.

220. Of the two kinds, which is the most rich in carbon?

Of the two kinds of mineral coal, anthracite contains the highest percentage of carbon.

221. Describe anthracite coal?

Anthracite coal, the most condensed of mineral fuel, is hard and varies in color from a glistening black to dark lead-gray. It is clean, ignites with difficulty, burns with a short flame, without smoke, and has very little illuminating power. When

burning it throws off a penetrating, sulphurous odor, but gives an intense, concentrated heat.

222. Of what does anthracite coal consist?

The constituents of anthracite coal are carbon, water, and earthy matter in accidental and varying mixtures. Anthracite is the condensed coke of bituminous coal.

223. What is the usual percentage of carbon contained in anthracite coal?

The percentage of carbon in Pennsylvania anthracite ranges from 85 per cent. to 92 per cent. In the anthracite of South Wales the carbon has been found to reach as high as 95 per cent., and in a Russian variety 94 per cent.

224. What is the average percentage of ash?

The percentage of ash in anthracite coal ranges from 4 per cent. to 8 per cent.

225. Into what two classes are the anthracite coals divided?

According to the color of their ashes, produced in combustion, the anthracites are divided into two classes, known as "red ash" and "white ash."

226. What are the characteristics of anthracite "red-ash" coals?

The anthracite red-ash coals contain a considerable proportion of oxide of iron, which gives them a reddish color. They are generally more easily kindled and a more free-burning coal than the white-ash, but from the liability to clinker, or from cinders, which melt and adhere to the walls of the grate or furnace, they are not so much esteemed for purposes which require considerable draught as the white-ash variety, which shed their ashes freely. For burning in open grates or for domestic use, with a moderate draught, the red-ash coal is preferred.

227. Describe the physical characteristics of anthracite "white-ash" coals?

The anthracite white-ash coals are harder than the red-ash and are more suited to carry the burden of ore in a blast-furnace or for any use requiring a strong draught for combustion, as in large heating furnaces, or under boilers having a forced artificial draught.

228. How is the relative value of fuels determined?

The relative value of fuels is determined by the quantities of water evaporated by a certain weight of each fuel.

229. What do these evaporative tests show?

Coals tested in this way show that the richer a coal is in fixed carbon the greater is its heating power.

230. Under this test which coal would class highest in value?

Anthracites would class higher in value than the bituminous coals, weight for weight, owing to the higher percentage of fixed carbon which they contain.

231. How much water will one pound of Pennsylvania anthracite coal evaporate?

It has been shown by laboratory experiments that one pound of Pennsylvania anthracite coal will evaporate 15.56 pounds of water.

232. How much water will one pound of bituminous coal evaporate?

A pound of the best Scotch coal by the same experimental tests evaporated only 7.74 pounds of water, and of the best English bituminous only 9.07 pounds of water.

233. Are these laboratory tests conclusive proofs of the relative value of the two kinds of coal?

They are not, as these results, it is well known, are not sustained in actual practice.

234. What is the generally accepted theory of the actual relative values of fuels?

It has been proven that the heat value of fuel is proportional to the quantity of oxygen which enters into the combination, whatever may be the nature of the combustible. As hydrogen and the gaseous products of its combination with carbon consume much larger proportions of oxygen than the same weight of solid carbon, the presence of these increases the heating power of the fuel.

235. By this rule which coal would class the highest in value?

The heavy gas coals would class higher in value than the anthracites, weight for weight, owing to the higher percentages of gaseous matter and volatile substances which they contain.

236. Is this rule sustained in actual practice?

It is not, owing to the difficulty of obtaining perfect combustion. All experiments made with the purpose of ascertaining the relative value of fuels should be made in the particular apparatus especially designed for the best combustion of each kind of fuel. When this is done it is found that each kind of coal is adapted for some particular

use in preference to the others, and that no marked superiority is peculiar to either.

237. Describe bituminous coal?

Bituminous coal, unlike anthracite, is usually soft, friable, and easily crushed or broken into small cubes or fibrous-like pieces; like anthracite, it varies in color from a bright, shiny black to dull gray. It ignites easily and burns with a long, reddish flame, interspersed with vivid jets of bright, highly illuminating power, and gives an agreeable heat, diffused over the entire mass.

238. Of what does bituminous coal consist?

Bituminous coal consists of carbon, volatile matter, water, and ash; it differs from anthracite in its higher percentage of volatile gases and its lower percentage of carbon.

239. What is the usual percentage of volatile matter in bituminous coal?

The percentage of volatile matter in bituminous coal varies greatly,—from 15 to 18 per cent., as in the Cumberland, Maryland, and Clearfield, Pennsylvania, coals, to 35 per cent., and even 45 per cent., as in the West Virginia, Ohio, and Indiana coals.

240. How do we distinguish the volatile matter in coal?

In the combustion of bituminous coal the volatile matter it contains is seen in the flame which it produces.

241. What percentage of carbon is found in bituminous coal?

The percentage of carbon contained in bituminous coal varies from 50 per cent. to 80 per cent. The higher the carbon the less will be the volatile matter, and, conversely, the higher the volatile matter in coal the less will be the carbon.

242. What constitutes the energy of coal?

The energy of all coals is in the combined carbon and volatile matters which they contain. These two added together constitute the strength or body of all fuels, varying as their combustion is more or less perfect.

243. Then a large percentage of carbon in coal does not indicate the most energy?

Not necessarily so. If such was the case, many of the poorer grades of Russian coal would be found superior to our heavy gas coals in steaming properties, which is not the case in practice.

244. Does a large percentage of volatile matter in coal indicate superior strength or energy?

Not always. Many of our Western coals, ranging the highest in heavy hydrocarbons or volatile combustible gases, give the poorest results in effective energy or steam-raising power.

245. What do we learn from these examples?

We learn that a coal may be high or low in volatile matter or fixed carbon in its chemical analysis and give entirely different results in practice than such determinations would indicate.

246. Of what use is a chemical analysis of coal?

A careful analysis of coal will determine the amount of impurities which it contains, such as ash, sulphur, phosphorus, or other harmful constituents. It also, in a great measure, determines for what uses the coal in question is best suited. For example, a coal high in volatile matter and carbon and low in ash would indicate a powerful fuel with great effective energy, while it might also contain a high percentage of sulphur, rendering it unfit for the manufacture of iron; on the other hand, a coal may be comparatively free from sulphur, high in carbon, and so low in the heavy volatile matter and density as to be entirely unsuitable

for heavy steaming or for combustion under forced or artificial draughts.

247. Into what two classes is bituminous coal generally divided?

According to the percentages of volatile matter which they may contain, bituminous coals are generally divided into two classes, known as steaming coals and gas coals. These are also frequently designated as bituminous and semi-bituminous, and are again subdivided as "block coal," "cannel coal," "coking coal," etc.

248. Name some of the best known semi-bituminous steaming coals?

Among the semi-bituminous coals of Pennsylvania are those known as "Clearfield," "Broad Top," "Reynoldsville," "Allegheny," "Blossburg," "Barclay," "Snow Shoe," "Meyersdale," "Mercer," and "Dagus;" and of Maryland, the "George's Creek," Cumberland.

249. Where are the principal beds of gas coal in the United States?

The principal beds of gas coal in the United States are in the country adjacent to Pittsburgh, Pennsylvania, and southeasterly along the Allegheny range in West Virginia.

250. Which is the most important of the coking coals?

The principal bed of coking coals is also found in Pennsylvania, in the neighborhood of Connellsville, and in West Virginia.

251. What is the principal kind of coal found in Ohio, Indiana, and Illinois?

That which is classed as bituminous. The "block" coal found in a part of Indiana, having a peculiar fracture into cubical blocks, is of special value for furnaces.

252. Describe "block" coal?

Block coal has a laminated structure and is composed of alternate layers of dull black coal and mineral charcoal. It splits readily into sheets, but with difficulty is broken in the opposite direction. It swells very little in burning, does not change form, and never cokes or runs together. It is pure and free from sulphur.

253. What original causes produced the difference in the various coals?

The mixed and ever-varying deposits of carbon and clay of an original vegetation. In the Carboniferous age the coal vegetation was dense or otherwise, producing the different kinds of coal under various conditions.

CHAPTER SEVEN

PROSPECTING.

254. How is coal discovered?

The discoveries of coal are usually made by systematic prospecting in the rocks which are known to be of the coal-forming period. Accidental discoveries of coal have been made by persons ignorant of geology, but the principal coal fields of America have been developed by the trained prospector.

255. What is a prospector?

A prospector is one who explores a country in search for anything, but usually for minerals. A person who by education or experience is qualified to search for coal is called a coal-prospector.

256. What is the most common evidence on the surface of coal beneath?

The outcrop of coal seams which by accident or natural causes have become exposed on the surface of the ground. Often, however, the cover of alluvial matter is so great as to completely conceal the underlying seams of coal.

257. Of what use is this covering of nature?

In this alluvial covering is the soil given us for cultivation; but apart from that, were the coal seams denuded and exposed to the elements, the coal would rapidly deteriorate and the mining operations be frequently stopped by heavy rains or snow. The surface or covering provides shelter for the mines and natural channels by which all surface water is carried to the adjacent rivers.

258. Which is the proper term, a "coal vein" or "coal seam"?

Originally a deposit of coal in the ground was usually called a coal vein, but this was before the orderly continuity of the coal deposits was known or understood. The word "vein" as applied to minerals occurring in veins which radiate from the centre, like gold or silver, is correct, but coal never is found in this manner, but always as a thin sheet, bed, or stratum, and enclosed in parallel strata of rocks; it should therefore be called a "seam."

259. Are the coal seams uniformly level?

Not always. In fact, the case seldom occurs where the beds of coal do not vary from a slight rise or fall to a considerable angle of inclination; but in whatever position they may happen to be found, each particular seam of coal will be contin-

uous, level, or rolling, as the case may be, but extending over the entire coal field and exhibiting the same general characteristics, excepting at such points where its continuity is broken by natural or accidental causes.

260. How does a prospector search for coal?

In his search for coal the prospector examines carefully the surface and the exposed edges of rock strata on the banks of streams, rivers, and gullies. He also considers the position of the rocks, their probable displacement by drift or glacial action, the positions of detached boulders, and the causes of their probable removal from more distant localities. He examines old wells, the river-beds at extreme low water, all railroad and canal cuttings and quarries, as well as collections of local geological specimens.

261. Should any of these specimens contain the Carboniferous flora, what would that indicate?

The coal-prospector would know that the rock containing the geological fragments belonged to the typical coal measures, and therefore he would have good prospects of finding coal in the neighborhood from whence the specimen came.

262. What is the usual first indication of coal?

The first indication of coal when found near the surface is the "black smut;" or, if search is made

in ravines or beds of rivers and streams, the prospector looks for small bits of coal, like small black pebbles, continuing his search up stream until such fragments disappear, at which point the coal crop is close at hand.

263. How is the coal seam located?

Selecting the most likely spot, a small square excavation is made on the hill-side, as if digging a well, and when the seam of coal is reached an open drift or ditch is dug from the excavation of sufficient grade to drain away all accumulating water

264. Supposing the surface to be very abrupt and precipitous, how would we proceed?

In that case the preliminary excavations would be made directly into the coal seam by a small drift or tunnel.

265. How are the positions of the bituminous coal seams usually seen on the surface?

The positions of the various bituminous coal seams are plainly indicated in the "benches" or terraces of the hillside, which usually occur at the outcrop.

266. How are these benches formed?

Coal benches are caused by the process of erosion, which works more rapidly and easily on the

soft coal outcroppings than upon the enclosing rocks, thus producing the steps, terraces, or benches in the hillside.

267. What good indication of coal can be found in water?

Where a river or stream deposits a light yellowish covering along the banks and over the stones and other objects in its course, we know that the water contains iron and that it probably originates in a bed of coal.

268. What other means besides patient searching have been employed to discover coal?

There are a great many recorded instances of the discovery of coal by means of the *virgula divinatorum*, or divining rod, which are more curious than instructive. It is said that coal was thus discovered in France in the latter part of the twelfth century.

269. Can a prospector always depend on surface indications to locate a coal seam?

It is only under certain conditions that the coal seams can be located by the topographical or surface indications. The great amount of drift composed of soil or alluvial covering often completely hides the coal outcroppings and the position of the coal strata from view.

270. When such is the case, how must we proceed?

When no surface indications can be obtained, after thorough search has been made, we must ascertain what is contained in the ground by boring or drilling holes from the surface. These are called "prospect holes."

271. Where should such drillings be made?

In selecting spots for drilling, the prospector should first locate on the surface the probable course of the underneath tunnel or entry to the best of his knowledge and judgment. On this line, at measured distances, which are accurately noted in a record book, the points are marked as suitable spots for drilling.

272. What is the most simple form of drilling?

The most simple form of boring is with a "bit," or iron chisel, similar to that used by stone-masons for drilling holes in stone, and used in the same manner,—alternately raised and dropped as the hole is driven deeper, and turned partly around with each drop, so as to cut a round hole and prevent the tool from being wedged fast in the rock.

273. How is the "bit" raised after each drop?

In drilling with the bit and rods a spring-pole—sometimes a young growing tree bent over—is used

to lift the bit after each drop. The alternating motion up and down is done by hand power, or a stirrup is attached for the driller to use his feet; hence the expression, "kicking down" a hole.

274. How do we proceed as the hole becomes deeper?

As the work progresses sections of iron or wooden rods are fastened to the chisel until the required depth has been reached.

275. How is the nature of the strata ascertained through which the drill is progressing?

When some depth has been reached by the "bit" and rods they are withdrawn, and the broken bits of rock are taken from the hole by means of a "sludger."

276. What is a sludger?

A sludger is simply a short length of iron pipe fitted at the bottom end with a foot-valve or traps, so that the churning of the sludger up and down will gather up the pieces of rock inside the pipe, which—the valve preventing them from falling out—are drawn to the surface and there carefully examined for indications of coal. For this purpose it is necessary that the hole be kept wet by pouring water into it as the work advances.

277. How are the rods and bit withdrawn from the hole?

The rods and bit soon become too heavy to be withdrawn from the hole by hand. It is then necessary to withdraw them by means of a rope attached to a pulley and derrick.

278. To what depth can a hole be bored by the bit and hand power?

Holes have been driven by this system to a depth of 900 feet, but ordinarily it is not advantageous to a depth of more than 50 to 75 feet. Should the coal seam lie deeper, it would then be necessary to use a power drill.

279. What is a power drill?

A power drill is one worked by other than manual labor, as steam, electricity, or compressed air. Usually it is made like a hollow cylinder, and is furnished at its base or cutting end with a row of teeth like a saw, or with four or six bits, or generally with small pieces of black diamonds or carbons, in which case it is called a diamond drill.

280. What advantage does the power drill possess over the bit and rods?

By this system of drilling a more perfect specimen of the strata is obtained, as it cuts a solid

"core" or cylinder out of the rock, which can be brought to the surface by a spring grapnel, and can there be carefully examined and recorded. It has the additional advantage of being able to drill holes in any direction from vertical to horizontal, like a common auger.

281. Describe the "core" usually found when drilling for coal?

When boring for coal the drill first passes through the soil or clay, and then through the overlying strata of limestone, sandstone, etc., until when the coal measures are reached it penetrates the black shales, and often minute, thin seams of coal called "riders."

282. When the "rider" has been discovered, is the prospector sure of success?

Not always, as there may be nothing else in the property; but usually the "rider" is found in close proximity to the coal seam itself, and the probabilities are that the drill will soon drop into the soft, yielding bed of coal, and the prospector's task will be finished.

CHAPTER EIGHT

DEVELOPMENT.

283. The prospector having found the coal seam, what is the first step in its development?

The first step in developing a seam of coal is to ascertain the best location for an opening into it. This must be done with rare good judgment, as on this depends all the future working of the property.

284. By whom should this work be done?

To the trained judgment of a competent mining engineer should be left the location of the first or initial opening of a coal seam, and only men of technical knowledge and experience should be employed for this purpose.

285. What are the different methods employed for developing a coal seam?

In the United States we employ four methods of opening a coal seam,—namely, the drift, the slope, the tunnel, and the shaft, which are adopted according to the nature of the surface and the position of the coal seams.

286. What is a drift mine or opening?

A drift opening is very simple. It consists of a small opening, about 6 feet high and 8 feet wide, "drifted" or driven into the coal seam from the outcropping and making a small tunnel in the coal itself.

287. Where should a drift opening begin?

The point selected for beginning a drift opening should be at the lowest part of the outcrop, so that any water met with in the mine will drain out of it, and also that the coal can be easily hauled on a down grade from the interior to the tipple, or loading platform.

288. What is the cheapest mode of opening a coal seam?

A property opened by "drifting" at the lowest part of the outcrop and progressing into a hill at a slightly ascending uniform grade is the cheapest and most favorable way in which a coal seam can be opened.

289. What is this mode or system called?

When a coal seam is opened in this way the coal is "taken on the rise," as it is called by miners.

290. What is the reverse of this system called?

Where the grade of the drift is slightly descending as the work progresses the coal is said to be "worked on the dip."

291. Why is the first method the best?

In the first instance the drift is always dry and free from water, as it runs out of itself, while in the latter case the water is always ahead of the workings and just where it is the most troublesome, —at the "face" or end of the drift or tunnel.

292. Why is not the drift opening universally adopted?

Circumstances are rare where the coal seams are so favorably located as to furnish opportunities for drift openings. They are not usually found in such advantageous positions.

293. What is a tunnel mine or opening?

A tunnel opening is a drift through intervening rock measures to the coal beyond. To illustrate a tunnel opening one must suppose the coal seam, instead of lying flat and parallel to the horizon, to be inclined from the outcrop high up on a hillside and pitching downward into and through the hill. The outcrop being too high, or possibly not exposed, a tunnel is driven into the side of the hill

through the rock at water level until the coal is reached; the coal is then mined and hauled out to the tipple through the tunnel.

294. What circumstance determines the desirability of using the tunnel opening?

The length of the tunnel required to reach the coal would determine the desirability of this mode of opening. For if the distance were too great through the rock the cost of opening would be very great also, and the distance necessary for hauling the coal, if very long, would add too much to the cost of operating.

295. What is a slope mine or opening?

Where the coal seam crops out at the surface and is at an angle, the most common way of opening the seam is by a slope, which is exactly similar to a drift, the main gangway or entry being driven into the coal itself, but is not level, the drift following the dip of the coal downward or in a sloping direction into the hill; hence the term a slope mine or opening.

296. How is the coal mined in a slope opening?

When the principal drift has reached a suitable distance down and into the coal seam, gangways or cross headings are driven, at right angles with the

main opening, along the "strike" of the seam, and the mining of coal begins at this point.

297. What is the "dip" and "strike" of a coal seam?

The "dip" of a coal seam is its angle of inclination measured from a horizontal line. The "strike" is the direction of any horizontal line along or across the seam. It is always at right angles to the "dip." An excellent illustration of the dip and strike of a coal seam can be had in a sheet of note-paper held so that one part is horizontal and the other hangs down. The angle which the hanging leaf makes with the other is the "dip," and the line where the two leaves are connected is the "strike."

298. At what angle of inclination in the coal seam is it best to open it with a slope?

Where the dip of the coal seam inclines from the horizontal more than 15 or 20 degrees it is best to work the seam by a slope.

299. What is a shaft mine or opening?

Where the coal seam is found in a flat country and lying horizontally some distance or, as is often the case, below water level, the opening is made by "shafting;" that is, sinking a shaft or hole from the surface to the coal seam below. A mine thus developed is called a shaft mine.

300. What is the advantage of a shaft mine over the other methods of development?

The advantage in opening a seam of coal by a shaft is that it frequently permits the operator to penetrate the heart of the seam at once and to extend his workings in every direction. There is no "crop coal" to work through, as in the drift or slope openings.

301. How is a shaft opening made?

In the United States the most common way is to begin by sinking a square or rectangular hole through the surface earth until the bed-rock is reached. This surface earth does not often exceed a depth of over 20 feet, and must be kept from caving in during the progress of the work and thereafter by stout timbers framed together or by a stone curbing, as in a well. When the solid rock has been reached, this timber or stone curbing sets firmly on it, and no further timbering is necessary until the sinking is completed and the coal has been reached.

302. What is the proper size for a shaft?

The size of a shaft depends entirely on the use for which it is intended. The *width* is seldom over 12 feet; it is regulated by the length of the small mine cars in use in the mines; the *length* by the

number of compartments intended to be used in its operation; the *depth* depends, of course, on the position of the coal seam.

303. What is the size and number of compartments used in a shaft?

A compartment is usually from 6 to 8 feet broad, so that the surface opening for a shaft with 2 compartments, the smallest in use, would measure 12 feet wide by 18 or 20 feet in length; a surface opening for 6 compartments, an unusually large one, would measure 12 feet wide by 40 or 50 feet in length.

304. Is the size of a shaft opening the same for its entire depth?

The first sinking of the shaft through the surface soil and earth is made from 4 to 8 feet longer than the size of the shaft in the rock, in order to give room for the timber or stone curbing along its sides.

305. How is the shaft-sinking done?

The excavating through the earth is done by a windlass, or the earth is shovelled on stages or platforms and then carted or wheeled away. When the rock is reached, holes are drilled into it, either by hand or power drills, and the rock is removed by blasting with powder or other explosives.

306. How is the coal worked after it has been opened by a shaft?

When the coal has been reached at the bottom of a shaft, a "sump" is excavated on the dip or lower side in the coal. This sump catches all the water, which from it is pumped out to the surface. After the sump has been excavated, working gangways are driven right and left into the seam, and from them are turned the "rooms" in which the miners work the coal.

307. What is the ordinary depth of a coal shaft in the United States?

In this country a shaft is seldom sunk over 300 or 400 feet in depth. The deepest shaft we have is in Pottsville, in the anthracite region,—about 1600 feet.

308. How do these shafts compare with those in Europe?

In the European coal fields much deeper shafts are sunk than in the United States to reach coal seams not nearly so thick. It is not unusual to sink shafts there from 1000 to 3000 feet in depth.

309. What is the average time required to sink a shaft?

The time required to sink a shaft under ordinary conditions has been estimated at 200 to 300 feet per year, including timbering.

310. What is the cost of sinking a shaft through hard rock?

The cost of sinking a shaft through hard rock is placed at $5.00 to $8.00 per cubic yard for rectangular shafts of an average cross-section and from 400 to 800 feet deep. The cost increases rapidly with the depth, and for shafts more than 800 feet deep the cost per cubic yard may reach $10.00.

311. What is the cost of sinking a shaft through shale and sandstone?

Under ordinary conditions, a shaft sunk through shale and soft sandstone would cost, on an average, from $2.00 to $5.00 per cubic yard for shafts from 500 to 800 feet in depth.

CHAPTER NINE

OPERATING.

312. How many men are employed in operating the coal mines of the United States?

The production of coal in the United States at present requires about 365,000 men, who are employed in operating the mines.

313. How are these divided between the anthracite and the bituminous mines?

Of this number 135,000 are employed in the anthracite regions of Pennsylvania, while the remaining 230,000 are scattered over the other coal-producing States, engaged in the mining of the various bituminous fuels.

314. Are women and children employed in the coal mines?

Such was the case in England and France for years; and in Scotland, within the past fifty years, women and children were employed to carry coals on their backs from the mines to the surface. Now, women no longer work in the mines in England or France, but are still so employed in Belgium. In

the United States, women have never worked in the mines, and the employment of children underground is, in most of the coal States, prohibited by law.

315. How were the earlier mines of the United States operated?

The early coal tonnages in the United States were produced by very crude and simple methods. When the coal outcropped on the hill-side it was dug out with pick and shovel, or, if shafting was necessary, a rude crank and windlass was all the machinery used.

316. How do we operate now?

To-day the "main entry" in a coal mine is laid out with the precision of a main avenue in one of our cities by competent technical experts, and from it at right angles are driven the "headings" like so many cross streets, lined on either side with the "rooms" or daily workshops of the miners.

317. How much coal can a miner produce in a day?

A miner can produce from 5 to 8 tons of coal daily, depending upon the thickness of the seam, the nature of the roof, the condition of the mines, and various other circumstances, such as water, gas, etc.

318. What are the tools used by a bituminous miner?

His tools consist of several picks, a shovel, an auger, tamping bar and needle, a small hat lamp and can of oil, and also a can of powder.

319. How does he mine the coal?

With his pick he digs away a space at the bottom of the seam, to accomplish which he must lie down on the floor of the mine while he works his arms, "undercutting" the coal. This undercut slopes gradually downward, until he has undermined a space clear across the room, as far as he can reach under the coal with his pick. This done, he takes his long crank auger, places a small piece of board across his breast against which to rest the end of the crank, and bores a hole into the top of the coal at an upward angle, taking care not to bore deeper than the undercut. Next he makes a cartridge by wrapping a piece of paper about a round stick the size of a broom-handle, which he withdraws, and the paper shell thus made is filled with blasting-powder according to the desired size, usually six or seven inches in length. The cartridge is then stuck on the point of the tamping needle (which is a slender pointed rod of iron, five or six feet long) and forced into the hole with the tamping bar, which is a heavy iron rod, with a head at one end through which a groove runs to fit the

needle. The miner then tamps in the cartridge with damp coal-dust as solidly as possible. The needle is then withdrawn, leaving a round hole leading to the powder in the cartridge. A lighted squib is thrust into the hole, and the miner seeks a place of safety. The squib is about the size of a slate-pencil, and the moment it begins to burn it rushes forward to the powder, which it explodes, blasting down the coal.

320. How much coal will a blast dislodge?

A single shot will sometimes dislodge a ton or two of coal, while often it has no effect at all, and the work must be done over; this is called a "blind shot."

321. What is done with the coal after blasting?

When the coal is knocked down, the miner carefully examines and shovels it into a small mine car, holding from one to two tons, which he shoves from his room to the heading; there the drivers attach the mules, couple the cars together in strings and haul them to the bottom of the shaft, or, if a drift working, out of the mine to the colliery or tipple, where the coal is dumped into the large railroad cars, in which it is shipped to the consumer.

322. How is a miner paid for his work?

In this country a miner is always paid by the ton or wagon. He does the work by contract, furnishes his own tools and material, and, of course, must keep them in order. His contract is to blast down the coal, put it in the mine cars, and push the cars from his room to the entry. All other work is paid for by the operator.

323. What other work is there to do?

The main headings must be timbered and ditched, iron or steel rails must be laid for the mine cars, room must be made for the mules to walk; and for this purpose the "bottom" of hard fire-clay must be taken up, or the "roof" of harder rock must be taken down, air courses must be driven, and rooms turned or opened and ventilation provided. All this is called "dead work," and is paid for by the yard or day's work by the operator.

324. What other expenses are paid by the operator?

The operator must also purchase the land on which the seam is located, or pay a royalty per ton to the land-owner. He must pay all the expenses of opening the seam, and for all the buildings, cars, mules, and machinery necessary for conveying the coal from the main entry underground to the con-

sumer. When the miner conveys the coal to the main entry he is done with it.

325. What is the most necessary thing to consider in working a mine?

Ventilation, by which is meant a proper supply of air from the surface to the miners underground.

326. Why is the air in the mines not sufficient for this purpose?

The air in a mine is never the same naturally as that on the surface, owing to the admixture of certain gases which issue from the coal and rock as the work progresses.

327. How is air admitted to the mines naturally?

In the mines a natural current of air passes down the slope or shaft, or into the drift mouth, and thence along the various entries and cross-cuts, as water is conveyed through pipes, sometimes sluggishly and then more rapidly, according to the energy applied in its transmission from the surface. In natural ventilation this energy is nothing more nor less than the difference in temperature between the surface and the interior of the mines.

328. How does this difference in temperature produce a movement of the air underground?

All gases, including the air, which is a mixture of gases, expand as they become heated, and become lighter as they grow warmer. If, therefore, we have a temperature high on the surface and low underground, or *vice versa*, the tendency of the warm air is to rise, being lighter, and of the cold air to displace it, being heavier. This action on the surface we call "wind," but underground it is called an "air current." In the extremes of summer and winter seasons we have a difference in temperature between the air in the workings and the air on the surface, sometimes as much as 50 or 60 degrees. These differences cause a lively movement of air through the mines.

329. Is natural ventilation sufficient?

It might be, if there were no other influences at work vitiating the air of mines, such as occluded gases.

330. What are occluded gases?

The formation of coal included the growth and decay of vast quantities of vegetable matter, covered in course of time with deposits of mud, sand, and gravel. This decay or putrefaction, continuing under the heavy mass of covering, produces an

enormous amount of gases, which, having no means of escape, are imprisoned in the coal-seams, awaiting the miner's pick and drill to set them free.

331. Under what names are these gases commonly known?

These gases are commonly known as "marsh-gas" and "fire-damp," and, weighing about half as much as the atmosphere, are usually found in the holes and fissures of the mine roof; when liberated and mixed with a certain proportion of air they become dangerously explosive.

332. What is carbonic oxide gas?

Carbonic oxide gas is the result of imperfect combustion. It is often called "white damp," or "after-damp," because it is always present in the mines *after* an explosion from fire-damp. It has no color, taste, or smell, beyond the faint fragrance of violets.

333. Why is carbonic oxide gas particularly dangerous?

Unlike other gases, its proximity cannot be detected by the ordinary method of testing with lamps, and only one-half of one per cent. of this insidious gas in the atmosphere is sufficient to cause

death,—a death which comes instantly and without warning of any kind.

334. Where can carbonic oxide gas be seen?

It can be seen burning, in combination with oxygen, at any time by observing the little blue flames dancing over a fire of red-hot coals.

335. What is carbonic acid gas?

Carbonic acid gas is occluded from the coal seam, and is also produced by the miners' burning lamps and the exhalations of men and mules in the mines. Being heavier than air, it is always found in a layer along the floor.

336. Is carbonic acid gas dangerous?

It is not particularly dangerous, unless the warnings of its presence are ignored and one should deliberately remain in it.

337. In that case what would happen?

In that case one would die of suffocation, as a person will in drowning. For this reason it is called "choke-damp," because it chokes or suffocates its victim.

338. How is the presence of carbonic acid gas detected?

The presence of carbonic acid gas in the air can be detected by the waning flame of a lamp. If a lighted lamp is plunged into the pure gas it will be instantly extinguished.

339. What percentage of carbonic acid gas in the air is necessary to cause death?

It is not known what percentage of this gas, mixed with the atmosphere, is necessary to cause death; 10 to 15 per cent. of it can be present in the air we breathe without serious inconvenience, beyond a dull headache or nausea; and in experiments made with animals as high as 30 per cent. has been used without causing death. This gas is more frequently found in old workings.

340. What other gas is generally found in old workings?

Sulphuretted hydrogen is another gas met with in old workings.

341. How is its presence detected?

The disagreeable smell of rotten eggs is sufficient evidence, in the mines, of its proximity.

342. What percentage of sulphuretted hydrogen in the air will cause death?

About 3 per cent. of this gas mixed with the atmosphere is all that is necessary to cause death.

343. How is an operator to prevent the contamination of the air in the mines?

An operator is powerless to prevent the intrusion of gases into the mines, or in many cases to detect their presence. All that he can do is to neutralize their ill effects by furnishing a generous supply of pure air to the mines from the surface.

344. How is this accomplished?

We accomplish this by means of artificial ventilation, and increasing the current of air passing through the mines by means of a furnace or a fan.

345. How is artificial ventilation produced with a furnace?

The operation is very simple. All mines are provided with a shaft sunk from the surface to the entries or gangways below, called an air shaft; this may be either a separate opening or part of the main hoisting shaft partitioned off for that purpose. A fire is maintained near the bottom of the

air shaft, and the heated column of air in the shaft, being lighter, rises and, the outer air taking its place, produces the necessary ventilation through the various rooms in the mines.

346. Give a familiar example of furnace ventilation.

A familiar example of furnace ventilation may be observed in any dwelling having an open fireplace, the chimney corresponding to the air shaft, or "up-take," and an open door in the hall-way to the drift mouth, or other mine opening. The doors of the various rooms represent fairly well the "trap-doors" in the mines, by which the current of air is "stopped off" from various parts of the mines as desired.

347. How is artificial ventilation produced with a fan?

By this method a current of air is forced *down* the air shaft and into the workings by the rapid revolutions of a machine run by an engine, which is constructed in many different patterns, but all having the same general resemblance to a paddle-wheel or propeller. Sometimes the operation is reversed, the machinery being so arranged as to exhaust or draw the air *up* the air shaft, and with it the obnoxious gases.

348. What is the average fatality among our miners by gas explosions and otherwise?

Statistics show that for every 100,000 tons of coal mined in our country one poor miner is killed by accident.

CHAPTER TEN

HAULAGE.

349. What is meant by the term "haulage"?

The miner having filled his small car with coal from his room in the mines, and pulled or pushed it into the main entry, his contract is finished, and the operator must now take the car and haul it to the surface. The various methods in use for this purpose are included in the general term of haulage.

350. What is the principal thing to avoid in haulage?

The most important thing to avoid in haulage is the rehandling of the coal,—that is, from one car into another, or to a common receptacle or heap, and thence again into wagons or cars.

351. Why is it necessary to avoid rehandling?

Because rehandling can only be done with labor, and labor is expensive.

352. Is this the only objection to rehandling?

The expense is not the only objection to rehandling. Coal is friable and easily broken, and each transfer produces slack, and deteriorates the quality

to such an extent that many of the softer coals are rendered unmarketable.

353. How was haulage done in the old times?

In the old times the coal was carried from the mines to the surface on the shoulders of men and women.

354. What system of haulage followed this in use?

This was followed by a system of hauling in which small sledges or wagons were pulled by boys. The chain used for hauling the wagon passed between the boy's legs, and was then hooked into an iron ring which was attached to a leather belt around his waist. In this manner the boys pulled the wagons along the gangways, using both hands and feet, like four-footed animals.

355. How is haulage done now?

Since the introduction of horses into the European mines, the heavy part of the hauling is done by them, and the manual labor is confined to pulling the wagons from the rooms to the main gangway, where they are made up into trains or "trips" and hauled to the foot of the shaft, or, in the case of drift mines, to the surface by horses. This is the case with us to-day, excepting that we generally employ mules instead of horses.

356. Why are mules preferred to horses?

In the darkness, under ground, a mule is more sure-footed and less liable to stumble over the cross-ties and uneven places than a horse. A mule is also less susceptible to sickness from hardships encountered in mine haulage, such as water, bad air, and constant drafts in the gangways. In certain places small mules can be used where, from his greater size, a horse could not enter.

357. What notable contrivance followed the introduction of horses?

With the introduction of horses into the English mines came also the iron tramway, or railway. These were the first railways ever built.

358. How were they constructed?

The custom was to lay two rails of timber, plated with iron, exactly straight and parallel, on which ran heavy wagons drawn by horses, or, in situations where the road was inclined, the loaded wagons were fitted with brakes, and were let down the inclines by gravity, the horses pulling them back when empty.

359. How are our mine roads constructed?

All of our mines are equipped with steel rails of the T pattern, of a section weighing from 16 to 40

pounds per yard, and are laid to a gauge of 3 or 3½ feet apart on cross-timbers, called "sills." They are connected at the points with two iron straps, one on each side of the rail, and bolted through like splices. These straps are called "fish-bars."

360. Describe a mine car?

A mine car is a small four-wheeled wagon, made of wood, iron, or steel, to hold from one to two tons of coal. They are made in every variety of style and shape,—some with flaring sides and others with straight sides. On some mine cars the wheels revolve loosely on a fixed axle, as in an ordinary road wagon; on others the wheels are fixed to the axles, which revolve in journal boxes, as in a steam railroad car. The usual weight of a mine car, when empty, is about one ton.

361. What is the average useful effect of one mule in haulage?

The average useful effect of one mule has been calculated by practice at from 20 to 50 tons hauled one mile per day. On roads of average grade it would probably be about 40 tons. If the car weighs one ton and carries two tons of coal, the useful effect in *tons of coal* is 20 tons hauled one mile per day by each mule.

362. How do the mules haul a "trip" of cars?

In hauling a "trip" of mine cars the mules are hitched tandem,—one ahead of the other, three, four, or five together,—the foremost mule, carrying a small miner's lamp attached to its head or hung to its collar, leading the others through the dark mine entries, seldom making a wrong turn or misstep. The driver sits on the front car.

363. Are locomotives used in the mines?

Sometimes small mine locomotives, weighing from 6 to 10 tons, are used in place of mules; but they can only be worked in mines that are free from gases and where there is plenty of air with quick ventilation. The danger from fire has always been urged against their use.

364. What other modes of haulage are there by locomotives?

If a locomotive is used the objectionable fire-box and boiler can be replaced by a compressed air receiver, or the haulage can be done by electric motors similar in operation to the familiar "trolley car."

365. How can haulage be done mechanically without locomotives?

There are various mechanical devices for hauling coal. The most common in use are as follows:

1st. Self-acting planes.
2d. Direct haulage.
3d. Tail rope.
4th. Endless chain.

366. Describe a "self-acting plane"?

Self-acting planes are simply inclined roads of sufficient grade for the loaded mine cars—attached to one end of a rope—to run by gravity down hill and haul up the same number of empty cars, which are fastened to the other end of the same rope. At the head of the incline, or at the top of the hill, a "sheave," pulley-wheel, or drum is fixed, around which the rope is wound.

367. What is "direct haulage"?

Direct haulage is a mechanical arrangement by which the empty wagons running down hill into the workings with sufficient energy to pull a haulage-rope in with them are then hauled out loaded.

368. Describe the "tail-rope" system of haulage?

A tail-rope is used where, the hill or incline not being sufficiently steep, there is not enough energy in the moving empty wagons to pull in the haulage-rope. In this case, a second or tail-rope of smaller diameter is used to pull the empty wagons and the attached haulage-rope into the workings.

369. How is the "endless chain" operated?

As its name implies, an endless chain passes from the engine along one side of the road around a pulley at the far end and back again on the other side of the road. The empty wagons are attached to one side of the chain by various kinds of clips or hooks, and are hauled *into* the mine. The loaded wagons are attached to the other side of the chain and are hauled *out* of the mine. This system is also called the "endless rope," when a rope is used instead of a chain.

370. Give a familiar example of "endless-rope" haulage?

A familiar example of this system can be seen operating the cable cars on Broadway, New York, the rope in this case being under the roadway instead of at the side.

371. After the coal has been hauled to the bottom of a shaft, how is it raised to the surface?

Many inventions were tried before we arrived at our present perfection in hoisting coal from the mines by means of great winding engines, which raise and lower the mine cars with certainty and precision.

372. How was "hoisting" done in the old times?

The oldest form of lifting the coal to the surface was by means of a "horse-whim." This method was employed as far back as the Middle Ages.

373. What is a "horse-whim"?

It consisted essentially of a wooden framework over the shaft, on which were fixed two wooden rollers or pulleys. From one of these rollers hung a rope, to the end of which was attached the *loaded* corfe or basket of coal; the rope passed over this roller and around an upright drum with three or four turns and thence over the other roller, and was attached to the *empty* corfe or basket. When the upright drum was made to revolve,—by means of an extended arm to which was hitched a horse, —the empty basket was lowered and the loaded one was raised to the surface.

374. What was the principal objection to this mode of hoisting?

The loaded basket or bucket, ascending, swung at the end of a vibrating rope, swaying back and forth in its passage up the circular well or shaft, while the descending empty basket also hung loosely suspended at the other end of the rope, and frequently they came together in the middle of the shaft with disastrous results.

375. How was this danger remedied?

To prevent this danger, the shafts were made square and fitted with cages having conductors at the sides. Upon these cages the loaded mine cars are wheeled and raised bodily, with their contents, to the surface, the empty car in its opposite cage descending simultaneously and without the possibility of a collision.

376. Give a familiar example of a modern hoisting apparatus?

An every-day example of this invention can be observed in its highest state of perfection in the passenger "elevators" of our hotels and tall office buildings. The speed at which these hoists are run was never considered possible by the engineers of the olden time.

CHAPTER ELEVEN

PREPARATION.

377. How is coal weighed at the mines?

In drift mining, when the coal has been hauled to the surface by mules or, through a shaft, slope, tunnel, or otherwise, by machinery to an elevated platform called a "tipple," the car and its contents are carefully weighed on a platform scales by a "weigh-boss."

378. What is a check-weighman?

A check-weighman is a man chosen by the miners and in their employ, receiving for his compensation one or two cents per ton on all coal mined and weighed over the scales. It is his business to see that the miners receive due credit for all the coal that they send out, and for this purpose he assists or checks the weigh-boss at the scales.

379. How does the weigh-boss know whom to credit with each car of coal?

To facilitate the matter, each miner, or sometimes two or three miners, will "work a number," —that is, a number—1, 2, 3, 4, etc.—is given them,

and all coal sent out on each number is so credited in the scale-house.

380. How is this arranged?

The number given to each miner is branded on small pieces of wood, or is stamped on small brass checks, like baggage checks; these the miners get at the scale-house every morning and take them into the mines; when a wagon is loaded, the miner sticks the numbered bit of wood into an iron staple placed on the side of the mine car, or hangs the brass check on a hook provided for the purpose. When the car reaches the scales, the weigh-boss or check-weighman removes the bit of wood or brass, and credits the coal on a tally-sheet to the number he finds upon it. This tally-sheet is hung up in the scale-house, and the numbered checks are carefully piled in little heaps for the inspection of the miners in the evening.

381. After the coal has been weighed, what becomes of it?

After the coal has been weighed, the mine car is pushed to the "tipple," and its contents tipped over into the large railroad car which stands on the siding underneath the platform. The dumping of the contents of the mine car is easily done by means of a swinging gate on the end, held in place

by a catch; when this catch is raised the gate swings open and allows the coal to fall into a chute, and thence into the railroad car below.

382. Is this simple form of loading suited to all kinds of coal?

This method of loading is suited only for shipments of coal which have had no preparation, or what is called "run of mine."

383. What coals are shipped in this way?

The semi-bituminous coals of Pennsylvania, Maryland, and Virginia, including the Clearfield, Cumberland, and Flat Top, the Punxsutawny, Blossburg, and Alleghany coals, and many others used for steaming and smithing.

384. How is bituminous coal "prepared"?

It happens with bituminous or gas coals that the customer requires a more clean and lumpy coal than "run of mine," in which case it is necessary to have it screened. Coal so prepared is known in the market as "lump," "three-quarter," "nut," and "slack."

385. How is lump coal prepared?

This is done by putting into the bottom of the chute long iron bars, set an inch and a half apart,

in place of the solid iron plates, thus making a screen 15 to 18 feet long. When the coal is dumped from the mine cars directly on these bars, the fine coal falls through the openings, and the lumps pass down *over* the bars into an iron platform suspended from the scales, where it is weighed and then loaded into the railroad car beneath; this is called "lump" coal.

386. What is "nut" coal?

The coal which has dropped between the bars set an inch and a half apart is caught on a second set of irons, which are placed only three-quarters of an inch apart, and while the finer coal drops between these bars, the lumps pass down *over* them. The coal passing over the bars is caught and weighed, and then loaded into the railroad car beneath. This is called "nut" coal.

387. What is "slack" coal?

In the operation described in the previous answer for making nut coal, the fine coal which passes *between* or through the bars set three-quarters of an inch apart is called "slack" coal.

388. What is "three-quarter" coal?

Three-quarter coal is simply a mixture of "lump" and "nut."

389. How are the miners paid for coals thus prepared?

In fixing the rate to be paid the miners for this kind of coal, a price is made only on the coal that passes *over* the screens, and is therefore proportionately higher per ton than the rate paid for mining the semi-bituminous coals, where run of mine is shipped entirely.

390. How are the different sizes of coal loaded into railroad cars?

The railroad tracks underneath the tipple are arranged so that the railroad cars intended for the different kinds of coal can be loaded by "dropping them down" a slight grade, one by one, into the proper position, a locomotive having first pushed the required number of empty cars to the head of the grade above the tipple.

391. How is coal loaded into river boats?

Where river transportation is available, the tipples are made to facilitate the loading of the coal directly into the barges or boats, which are towed into position under the overhanging chute, and are then sent down the river, whole fleets of them, as on the Monongahela River, near Pittsburg in Pennsylvania, towed by large flat-bottomed steamboats.

392. What preparation is necessary for anthracite coal?

Anthracite coal, after being raised to the surface, is prepared for the market with more thoroughness than either the bituminous or semi-bituminous coals. It is necessary that it be broken into various sizes, and that all slate, dirt, fine coal, and impurities be carefully removed before it is shipped.

393. How is this done?

This is done by erecting a large structure called a "breaker." Through this building passes the coal, where it is screened over bars, then hand-picked, crushed between rollers, run through separating cylindrical screens and chutes for another picking, and sometimes is washed in running water.

394. How is the coal made to pass through the breaker?

To accomplish this, the loaded mine cars are hoisted to the top of the breaker, sometimes 150 feet high, where they are emptied, and the coal finds its way by gravity through inclined troughs and over screens to the railroad car beneath.

395. Describe the process of preparing anthracite coal.

When a mine car comes from the mine, it goes directly to the dump, and the coal is dumped upon a set of inclined bars or into a chute or pocket, from which it is slowly fed under a gate and allowed to slide down over the bars. These bars are placed from three to six inches apart, and separate the coal into two portions that are to be separately treated. The portion passing *through* the bars is conveyed to a screen which separates the fine coal, called "pea," "buckwheat," etc. This screen is called a "dirt-" or "mud-screen."

The "broken" and "egg" sizes coming from the mud-screen are picked free from slate and sent direct to the pockets for shipment, or sent to the "pony-rolls" or "monkey-rolls" to be broken down into "stove" and "nut" sizes. That portion passing *over* the main screen-bars runs out upon the "platform," which is a flat or slightly inclined floor covered with iron plates, and is cleaned by the platform men. The slate and rock are picked out and sent down the rock chute, the good "lump" coal goes to the lump chute, and the "rough" coal to the "crusher rolls," to be crushed and again screened and separated into domestic sizes.

396. Into what sizes is anthracite coal prepared?

Anthracite coal is generally prepared as follows:

Lump	over bars about 7 inches apart.
Steamboat	through bars about 7 inches apart. over bars about 5 inches apart.
Broken	through a mesh $3\frac{1}{2}$ inches apart. over a mesh $2\frac{5}{8}$ inches apart.
Egg	through a mesh $2\frac{5}{8}$ inches. over a mesh 2 inches.
Stove	through a mesh 2 inches. over a mesh $1\frac{1}{8}$ inches.
Nut	through a mesh $1\frac{1}{8}$ inches. over a mesh $\frac{3}{4}$ inch.
Pea	through a mesh $\frac{3}{4}$ inch. over a mesh $\frac{1}{2}$ inch.
Buckwheat	through a mesh $\frac{1}{2}$ inch. over a mesh $\frac{5}{16}$ inch.

397. In what other manner is coal prepared for the consumer?

For the utilization of very small coal, several processes have been invented, by which the fine coal, or slack, is reduced to powder and burned in that form, or is made into briquettes by pressure or otherwise.

398. Describe the Wegener apparatus for burning powdered coal.

The Wegener apparatus is exceedingly simple. Coal, ground to pass through a sieve of 60 meshes

to the linear inch, is tipped into a hopper at the top, whence it falls upon a grating, by which it is retained. This grating is subject to a continual knocking action, which keeps the coal-dust falling through it in a cloud. The knocking is done by a wheel with vanes in it; the air enters here under the influence of the chimney draught, and, passing through the wheel, puts it in rotation. The shaft of the wheel is continued upward to the grating, where it operates the knocker 150 to 250 times a minute. The strength of the knock, and consequently the amount of coal passing, can be varied by means of a screw and a spring. The coal-dust in falling meets a rising air-current, and both are diverted through a side pipe into the furnace, the interior of which is lined with fire-brick for a length of 10 or 12 feet, and has, in addition, two fire-brick bridges. There is no grate, and there are no fire-doors, the combustion being watched through peep-holes. The cost of preparing a ton of coal by grinding to powder is about 25 cents.

399. How is coal made into briquettes?

The most common way is to first dry the fine coal-dirt carefully, and then mix it with a very small quantity of pitch; a machine, by pressure, forms the pasty mixture into briquettes, from the size of an ordinary brick down to a ball the size of an egg.

CHAPTER TWELVE

WATER TRANSPORTATION.

400. What is meant by water transportation of coal?

As the term implies, the carrying of coal from one place to another by means of boats, arks, or other vessels floated on the surface of the rivers, canals, or any body of water.

401. What was the first system of water transportation in use in this country?

The first transportation of coal by water was done by means of wooden arks, which were loaded with coal at the mines, and then floated down-stream with the current of the river.

402. What were the objections to this system of transportation?

The river-beds were shallow and full of rocks, so that the arks laden with coal were frequently wrecked, and then it was found that the descent of a river was as nothing when compared with the labor of returning up the stream.

403. How were these objections met?

A system by which boats could move in any desired direction with safety was introduced in the shape of numerous costly canals, which were built in different parts of our country.

404. How were the rivers rendered navigable up-stream as well as down?

By the introduction of steam, which changed the whole condition of river traffic; under its powerful impulse steamboats were soon plying on the Ohio and Mississippi Rivers, both up-stream and down.

405. About what time did this occur?

In 1811 the "Enterprise," a keel boat made at Marietta, but fitted up at Pittsburg with an engine and a stern-wheel, under an arrangement with Robert Fulton left Pittsburg on its trial trip, and afterwards ran between New Orleans and Natchez until 1814, when it was wrecked.

406. What was the size of the "Enterprise"?

The "Enterprise" was between 300 and 400 tons' burden, and cost $40,000.

407. Who of our foremost Americans first advocated the building of canals?

Washington, we are told, took a deep interest in the construction of canals, and largely through his instrumentality a charter was obtained from the States of Virginia and Maryland, and also valuable grants of lands and money, for the purpose of building the Chesapeake and Ohio Canal, connecting the waters of the Chesapeake and the Ohio River. Of this company Washington was the first president.

408. When was this canal built?

Work on it was commenced in 1828, and in 1850 it was completed for a length of 180 miles of the line, leading from Cumberland, Maryland, to Georgetown, District of Columbia. It is still used for the transportation of Cumberland coal.

409. For what purpose was the Union Canal projected?

The Union Canal was intended to improve the navigation of the Schuylkill River, and afterwards was made part of a project for uniting the waters of the Susquehanna and Schuylkill Rivers.

410. When was it first proposed?

The scheme was first proposed in 1760, but nothing was done until thirty years later, in 1790, when a company was formed with $400,000 capital, under the name of Schuylkill and Susquehanna Navigation Company.

411. What other canal scheme formed part of the Union Canal system?

A canal was projected at the same time connecting the waters of the Delaware and Schuylkill Rivers, so that produce coming down the latter from the West could be carried over and landed at the wharves of the merchants of Philadelphia.

412. What was the name of this company?

It was called the Delaware and Schuylkill Canal Company, and was chartered in 1792 with a capital of $400,000.

413. What famous American was at the head of these organizations?

Robert Morris, the famous financier of the Revolution, was made president, and was at the head of the organizations.

414. Was the company successful?

Unfortunately, they were overwhelmed with disaster, and were compelled to suspend operations

after an outlay of $440,000, an immense sum in those days.

415. What became of the projected canals?

In 1811 the Legislature passed an act to incorporate the "Union Canal Company of Pennsylvania," which new company was a union of the old "Schuylkill and Susquehanna" and the "Delaware and Schuylkill" Canal Companies. The old companies were dissolved and a new company formed of the stockholders of the old corporations, whose relative rights were adjusted in the new distribution of the capital.

416. How were funds provided to continue operations?

The mode of raising funds to continue operations on the Union Canal was furnished by the passage of an act in 1819 authorizing a lottery or series of lotteries, and giving the company a monopoly of the right of conducting lotteries in Pennsylvania. The State was also pledged to pay any deficiency of interest, up to 6 per cent., which the lotteries could not produce.

417. Was this mode of financiering peculiar to Pennsylvania?

It was not. It seems to have been a favorite resource with other States for the accomplishment

of similar schemes, notably in New York, Virginia, Connecticut, Rhode Island, Delaware, Maryland, and North Carolina. Pennsylvania, however, at that time was considered the great mart for nearly all the lotteries of the United States.

418. When was the Union Canal finished?

Work on the Union Canal was resumed in 1821 and finished in 1827, thirty-seven years after the commencement of construction and sixty-five years after the first survey.

419. Describe the route of the Union Canal.

The Union Canal was nearly 80 miles long, from Middletown, on the Susquehanna River, to a point on the Schuylkill River a short distance below Reading, and was adapted to the use of boats of 25 to 30 tons' burden. At Middletown it was connected with the Pennsylvania Canal, leading by various connections to Pittsburg and Erie, to Tioga in the north, and to the Bald Eagle on the West Branch of the Susquehanna. At Reading it was connected with the works of the Schuylkill Navigation Company leading to Philadelphia.

420. What was the cost of the Union Canal?

In 1828 the cost of the Union Canal was estimated at $1,600,000.

421. Name some of the other famous canals built for coal transportation.

Of the other famous canals built for that purpose, there were the Delaware and Hudson, the Erie in New York, and the Delaware and Raritan in New Jersey.

422. What was the cost of transporting coal by canal?

In 1838 the cost of transporting Cumberland coal from the mines to tide-water, Georgetown, D. C., by canal, was about $4.00 per ton.

423. What was the cost of mining the coal?

In the same year the cost of mining Cumberland coal was put at $1.00 per ton.

424. What was the price at tide-water?

In those times the price obtained for Cumberland coal f. o. b. in Baltimore was $6.00 per ton, and of Alleghany coal in Philadelphia, $7.00 per ton.

425. At what price are these coals sold to-day?

The maximum price for these coals, transported from the mines to tide-water by railroad, would be at present $2.25 per ton for Cumberland coal at Baltimore, and $2.00 for Clearfield coal at Philadelphia.

426. When was the Schuylkill Navigation Canal built?

In 1817 work was commenced on the canal of the Schuylkill Navigation Company, but it was not until 1825 that anthracite coal began to form the principal part of its tonnage.

427. How was Lehigh anthracite coal transported by canal?

Lehigh anthracite coal found its way to market by means of the canal of the Lehigh Navigation Company and the lateral channels, the Morris Canal and the Delaware and Raritan Canal.

428. How did the Lackawanna coals reach the market?

In those early days of canal navigation the coals of the Lackawanna region were transported to New York by the Delaware and Hudson Canal, 108 miles, thence by rail 18 miles, and then by river navigation 91 miles, or a total of 217 miles.

429. What is the route of the Delaware and Hudson Canal?

From Honesdale, on the Lackawaxen River in Pennsylvania, to Rondout, on the Hudson River, New York.

430. How was the coal transported on the Ohio and Mississippi Rivers?

Until 1850 all the coal shipped westward from Pittsburg was floated down the Ohio River in large flat-bottomed boats with the spring and fall freshets, each boat holding about 15,000 bushels. The boats were usually lashed in pairs, and were sold and broken up when their destination was reached. In 1850 steam-tugs were introduced on the rivers.

CHAPTER THIRTEEN

ANTHRACITE RAIL SHIPMENTS.

431. What advantage has a railroad over a canal for coal shipments?

Besides that of quicker despatch, railroads are advantageous in districts where canals, for want of water, would be impracticable. This advantage is often felt in mining districts, and sometimes by general trade, where it is necessary to cross dividing ridges at a level too high to obtain water for canal navigation.

432. When were the first railroads built in the United States for coal transportation?

About the year 1825 short lines of railroad for coal transportation were constructed in our country as feeders to the various canals. In that year the Schuylkill Canal was opened to Mount Carbon, then a suburb of Pottsville, in the anthracite coal regions of Pennsylvania, and Abraham Potts built a railroad extending half a mile in length for carrying coal to the canal, which previously had been hauled in wagons.

433. How was this railroad constructed?

The railroad was made of wooden rails, laid on wooden sills, and was operated by horses; a dozen or more small cars, holding 1½ tons of coal each, were usually coupled together and drawn in trains to their destination.

434. What are the principal railroads of the anthracite regions?

The railroads which transport almost all of the anthracite coal are the "Philadelphia and Reading," the "Lehigh Valley," the "Central of New Jersey," the "Delaware, Lackawanna and Western," the "Delaware and Hudson," the "Pennsylvania," the "Erie," the "New York, Ontario and Western," the "Delaware, Susquehanna and Schuylkill," and the "New York, Susquehanna and Western," their relative tonnages being in the order given.

435. What is the route of the Philadelphia and Reading Railroad?

The Philadelphia and Reading Railroad was built as an outlet for the anthracite coals of the Schuylkill region in Pennsylvania to tide-water on the Delaware River near Philadelphia. Its route is along the Schuylkill River from Pottsville to Philadelphia, 94 miles.

436. When was it first opened for traffic?

On January 1, 1842, the first locomotive and train passed over the whole line between Pottsville and Philadelphia.

437. How was the event celebrated?

The event marked an epoch in railroad shipments, and was celebrated with military display. The train consisted of 75 passenger coaches, containing about 2000 persons. In the rear a coal train followed, consisting of 52 cars, loaded with 180 tons of anthracite coal, which had been mined the same day in the Pottsville region.

438. What was the cost of building the Philadelphia and Reading Railroad?

The entire capital invested in the railroad at this time was a little over $16,000,000.

439. What was considered good work for a locomotive in those days?

An engine or locomotive that could draw 200 gross tons, on a level road, at a speed of from 10 to 12 miles an hour, was considered as in every way satisfactory.

440. What was the capacity of coal-cars in those days as compared with the present?

They were very much smaller, some holding but 3 tons of coal, and mounted on 4 wheels. The capacity of an 8-wheeled coal-car to-day averages about 30 tons, or ten times that quantity.

441. What equipment is used by the Reading Railroad for coal transportation?

In 1897 the Reading Railroad Company owned 500 freight and coal locomotives, 18,543 8-wheeled coal-cars, and four 4-wheeled coal-cars, used almost exclusively for rail shipments of coal.

442. What percentage of the anthracite tonnage is carried by the Reading Railroad?

The Philadelphia and Reading Railroad now transports 20.50 per cent. of the total anthracite tonnage, or about 9,000,000 tons, annually.

443. What was the origin of the Lehigh Valley Railroad?

In 1847 the Delaware, Lehigh, Schuylkill and Susquehanna Railroad Company was chartered. The broad scope of its title came from the four rivers of Pennsylvania of the same names, and its route was intended to connect the waters of these

rivers. It has since been merged into the Lehigh Valley Railroad.

444. What percentage of the Pennsylvania anthracites is carried by it?

The Lehigh Valley Railroad is credited with carrying 15.65 per cent. of the total anthracite tonnage, or about 6,800,000 tons, annually.

445. What car equipment is used by the Lehigh Valley Railroad in moving this tonnage?

To carry this coal from the mines to the customer requires 11,000 8-wheeled cars and 20,000 4-wheeled cars.

446. What special privilege is contained in the charter of the Delaware, Lackawanna and Western Railroad Company?

This company, having a charter antedating the present Constitution of the State of Pennsylvania, is one of the few railroad companies privileged to carry on coal-mining and selling together with transportation.

447. What was the origin of this company?

This was originally the Ligett's Gap Railroad, incorporated by special act of the Pennsylvania Legislature, approved April 7, 1832; chartered

March 19, 1849; name changed by special act of Legislature, approved April 14, 1851, to Lackawanna and Western; consolidated April 30, 1853, with the Delaware and Cobb's Gap Railroad (chartered December 4, 1850), and name changed to "The Delaware, Lackawanna and Western Railroad Company."

448. What percentage of anthracite tonnage is carried by this company?

The Delaware, Lackawanna and Western Railroad carries 13.35 per cent. of the anthracite tonnage, amounting to about 5,600,000 tons annually.

449. When did the Lehigh Coal and Navigation Company first begin business?

This company first began business in 1820 by sending forward the first shipment of anthracite coal ever made in the United States. It is one of the old pioneers in the coal development of this country.

450. Of what does it consist?

It controls the Lehigh and Susquehanna Railroad, a leased line of the Central Railroad of New Jersey, and the Lehigh Canal.

451. What percentage of the anthracite trade is done by this system?

The Central Railroad of New Jersey is given 11.70 per cent. of the anthracite tonnage, amounting to 5,000,000 tons, annually.

452. What is the coal-car equipment of the Central Railroad of New Jersey, and what does the system embrace?

It now requires 17,000 coal-cars to carry the tonnage of the Central Railroad of New Jersey, and its system embraces about 700 miles of railroad in the States of New Jersey and Pennsylvania.

453. What was the origin of the Pennsylvania Railroad?

Early in the fifties the State of Pennsylvania owned about 750 miles of canals and 120 miles of railroads, which for various reasons were transferred to the Pennsylvania Railroad Company, at that time building a railroad from Harrisburg to Pittsburg. Under this transfer the Pennsylvania Railroad Company acquired the "old State Road," running from Philadelphia to Columbia. It also secured the Harrisburg and Lancaster Railroad, intersecting the old Columbia Railroad at Lancaster. These arrangements gave the Pennsylvania Railroad its present "main line" from the Dela-

ware River at Philadelphia, across the State of Pennsylvania, to the Ohio River at Pittsburg.

454. What percentage of the anthracite tonnage is carried by the Pennsylvania Railroad?

This company carries about 4,800,000 tons of anthracite coal annually, or 11.40 per cent.

455. Give some account of the Delaware and Hudson Canal Company.

This company is one of the most important of the anthracite carriers. It was chartered in 1823, ten years before the Reading, and was the first railroad in this country to use a locomotive. Its canal at present forms but a small part of its system. The total length of railroad belonging to this company is 688 miles, and of canal 108 miles, from Honesdale, Pennsylvania, to Rondout on the Hudson River, New York.

456. What percentage of anthracite does it carry?

The Delaware and Hudson Company carries 4,200,000 tons of anthracite annually, or 9.60 per cent. of the total tonnage.

457. What was the origin of the Erie Railroad?

The old "New York and Erie Railroad" was chartered in 1832, and construction commenced in

1836 for a railroad of 6-feet gauge. The railroad was opened to Port Jervis and Binghamton in 1848, to Elmira in 1849, to Hornellsville in 1850, and to Dunkirk in 1851. In 1861 the road was reorganized under the name "Erie Railway Company," and in 1878 a third rail was laid, giving the standard gauge (4′ 8½″), from Jersey City to Buffalo, when the company was again reorganized as the "New York, Lake Erie and Western Railroad." In 1895 the company was again reorganized as the "Erie Railroad Company."

458. What percentage of anthracite coal is carried by the Erie Railroad?

The Erie Railroad carries about 3,400,000 tons of anthracite per annum, including that of the Pennsylvania Coal Company, or a total of 8 per cent.

459. Describe the Delaware, Susquehanna and Schuylkill Railroad.

This railroad was built almost exclusively for the transportation of anthracite coal. Its main line of track is from Drifton to Gowen in Pennsylvania.

460. What is its percentage of anthracite tonnage?

This railroad transports about 1,700,000 tons of anthracite each year, or 3.50 per cent. of the whole tonnage.

461. What is included in the New York, Susquehanna and Western Railroad?

This line extends from Jersey City to a point near Stroudsburg, Pennsylvania, where it connects with an affiliated line, the Wilkes-Barre and Eastern, extending to mines in the Wyoming Valley. A branch extends from the main line to Middletown, New York, and the Hudson River Railroad and Terminal Company, with which it was consolidated in 1893, extends from another point on the main line to coal shipping piers and freight sheds on the Hudson River at Edgewater. Total mileage about 230.

462. What percentage of anthracite coal goes over this railroad?

About 1,400,000 tons annually, or 3.20 per cent. of the total.

463. When was the New York, Ontario and Western Railway organized?

The New York, Ontario and Western Railway was organized in 1879 as successor to the New York and Oswego Midland Railroad. It carries anthracite coal from the Pennsylvania fields near Carbondale and Scranton to Oswego on Lake Erie, Cornwall on the Hudson River, and Weehawken in New York Harbor.

464. What is its percentage of the anthracite tonnage?

About 1,300,000 tons annually, or 3.10 per cent. of the whole.

465. What interest has the anthracite-carrying railroads in the mines?

Ninety-five per cent. of all the anthracite coal-lands in the United States is owned or controlled by these great transporting railroads, operating principally in the State of Pennsylvania.

CHAPTER FOURTEEN

BITUMINOUS RAIL SHIPMENTS.

466. Is Pennsylvania anthracite competitive with foreign coals?

No anthracite coal, at home or abroad, has been found to compare with that of the Pennsylvania mines, either in quantity or quality. It can therefore be said to have no competition with any other anthracite coal, and for this reason no tariff is necessary to protect the industry.

467. Can this be said of American bituminous coals?

On the contrary, American bituminous coals shipped by rail to points on the Atlantic coast-line are directly competitive with foreign bituminous coals shipped by water to the same points.

468. What prevents foreign bituminous coals from supplanting those of American mines at these points?

The tariff act approved July 24, 1897, which imposed a duty of 67 cents per ton on all coals containing less than 92 per centum of fixed carbon, a qualification which includes all bituminous coals. This, added to the fact that at present American

coals, owing to their proximity to the surface and greater thickness and continuity of the seams, can be mined cheaper than those of other countries, prevents them from supplanting the product of our mines at Atlantic coast points.

469. What is the average price of English bituminous coals at the mines?

In England the average price received on the bituminous coal tonnage, the largest in the world, is about $1.60 per ton at the mines.

470. What is the average price of American bituminous coals at the mines?

The average price received in America on the bituminous coal tonnage, the second to the largest in the world, is about 83 cents per ton at the mines.

471. If American coals are sold at about half the price of English coals at the mines, why is the tariff necessary?

The price given in both cases is that received for the coals loaded in cars at the mines. In England, however, the mines are at or very near the seacoast, while the nearest American bituminous mines to the seaboard are distant several hundred miles. To the price of American coals at the mines,

therefore, must be added the cost of railroad transportation to the Atlantic seaports, in order to compare both prices at those points.

472. How much should this railroad transportation cost?

No railroad at present can carry coal profitably for so great a distance at less than $1.00 per ton; with this amount, added to the average price of 83 cents received for American bituminous coals at the mines, the average price at the nearest tide-water point would be $1.83 per ton.

473. What other transportation expenses are added to American bituminous coals?

In America railroads under one management do not run direct from the bituminous mines to all the coast cities. Transfers must be made, and connections with different systems of railroads, or, as is most frequently the case, the coal must be transferred at the nearest tide-water point into vessels, for which another charge is made, to convey the coal by sea to points along the Atlantic coast-line, any one of which could be reached directly by vessels or steamers from England or her colonies in Canada by the payment of water transportation alone.

474. How much would this water transportation cost?

At certain times a nominal sum only, as English vessels frequently come to the United States in ballast, and English coal could be used for this purpose. The water transportation on Canadian coals to our Northern seaports is also sufficiently small to permit their entry free of duty in competition with American coals, paying both railroad and water freights.

475. What are the principal bituminous-carrying railroads on the Atlantic seaboard?

The bituminous-carrying railroads are the "Pennsylvania," the "Baltimore and Ohio," the "Norfolk and Western," the "Chesapeake and Ohio," and the "Philadelphia and Reading," with their various connections.

476. What proportion of tide-water bituminous coal is carried by the Pennsylvania Railroad?

About 46 per cent. of the bituminous tonnage coming to the Atlantic seaboard at Greenwich Piers, Philadelphia, South Amboy and Harsimus, New Jersey, and Canton Piers, Baltimore, is shipped over the lines of the Pennsylvania Railroad.

477. What is the bituminous tide-water tonnage of the Norfolk and Western Railroad?

This railroad transports to Norfolk annually about 18 per cent. of the tide-water bituminous tonnage over its piers at Lambert's Point, which is on the Hampton Roads at the mouth of the James River in Virginia.

478. What is the bituminous tide-water business of the Baltimore and Ohio Railroad?

The oldest of the bituminous coal carriers, the Baltimore and Ohio Railroad, now ships about 13 per. cent of all the seaboard tonnage from its own piers at Locust Point, Baltimore, on the Chesapeake; Jackson Street, on the Delaware River, Philadelphia; and St. George, Staten Island, in New York Harbor.

479. What is the tide-water tonnage of the Chesapeake and Ohio Railroad?

About 12 per cent. of the whole, which reaches the Atlantic seaboard at Newport News, on Hampton Roads, Virginia.

480. What proportion of the tide-water bituminous tonnage is carried by the Philadelphia and Reading Railroad?

The remaining 11 per cent. of the bituminous seaboard tonnage is carried by the Philadelphia

and Reading Railroad to Port Richmond, on the Delaware River, Philadelphia; Port Reading, on the Arthur Kill, or Staten Island Sound, New Jersey; or Port Liberty, on New York Bay.

481. What is the total amount of bituminous coal carried to Atlantic shipping ports annually?

The total amount of bituminous coal now handled over the various shipping piers on the Atlantic seaboard is estimated at about 30,000,000 tons.

482. How much of the bituminous regions in the United States are owned by the coal-carrying railroads?

The lands in the American bituminous fields are owned almost entirely by individuals, the transporting railroads having little interest in or control over them.

483. How much bituminous coal is there remaining in these lands?

It is impossible to estimate the amount of coal unmined in the bituminous fields of America; any figures given would be the merest guess-work. It is apparently inexhaustible.

484. How much anthracite coal is still unmined?

It has been estimated that about 5,000,000,000 tons of anthracite coal still remain unmined in the

Pennsylvania fields. This amount, at the present rate of production, will last just one hundred years.

485. Are the other American bituminous coals, excepting those coming to the Atlantic seaboard, competitive with foreign coals?

The bituminous coals transported westward from our interior mines by rail, and south by boats on the great rivers Ohio and Mississippi, are strictly for domestic use, and in no way competitive with any foreign product. Some imported coals are brought to our Pacific coast in competition with our mines in California, Oregon, and Washington.

486. What is the capacity of a railroad coal-car?

Railroad coal-cars are of every style and pattern, from the 4-wheel "jimmies," carrying about 5 tons each, to the 8-wheel "hopper gondola," with a capacity of 60,000 to 80,000 pounds (30 to 40 tons) each.

487. What is a 4-wheel "jimmie"?

A 4-wheel "jimmie" is a railroad car made of wood. They were the first cars made for the transportation of anthracite coal, and are now gradually disappearing from use.

488. What other kind of cars are used for coal shipments?

There are iron cars with 4, 6, or 8 wheels, with drop or hopper bottoms; flat or platform cars with side-boards, such as are commonly used for shipments to the Lakes, returning laden with ore or other tonnage. The most common form of coal-car for shipment of coal to tide-water is the hopper-bottom gondola of 60,000 pounds (30 tons) capacity, made of wood and having 8 wheels; these cars are equipped with air-brakes and patent couplers.

489. What is an "individual" coal-car?

An "individual" coal-car is one owned or leased by a coal operator, and not by the transporting railroad company. These cars have painted on their sides the names, initials, or some chosen trade-mark or emblem of their owners, and are run for their exclusive benefit. They are generally used between the mines and the coastwise shipping ports of the various railroads.

490. How is the coal discharged from hopper cars into vessels at tide-water?

Arriving at tide-water, these cars are first weighed and then run out on a pier or wharf, and the coal is dumped, by means of the drop-bottoms,

into the holds of vessels waiting to receive it. The vessel, having thus received her cargo of coal, is cleared for the various cities or towns along the Atlantic coast or adjacent harbors.

491. How is coal discharged from flat cars into vessels?

In some cases, at lake ports, the loaded car is run into a large iron cylinder, into which it is firmly clamped. The cylinder is then rolled up an inclined plane, causing the car to turn over, when the coal rolls out into a chute, and from thence into the vessel's hatches.

492. What is a coal barge?

Although coal can be moved by sailing vessels at very low rates, they sometimes fail to move promptly, and the service is often broken by trade conditions or the whims and personal fancies of their individual owners and captains. For these and other reasons large operators use coal barges towed by steamers, called colliers, or powerful sea-going tugs, for conveying their coal to coastwise destinations.

493. How are coal barges constructed?

Coal barges are built on the lines of a ship, in order to make them ride and handle easily in a sea.

They usually have three or four masts, with sufficient sail to make the nearest port should they break away from the towing steamer or tug.

494. What is the capacity of a coal barge?

Each barge carries from 1500 to 2000 tons of coal. The towing steamer or collier can also carry about the same amount of coal. A loaded steamer usually tows one loaded coal barge, and a tug will tow two or three together.

495. What is "bunker coal"?

Bunker coal is a term applied to supply coal consumed by the ocean steamers plying between our ports and all parts of the world. It is the coal put into a steamer's bunkers for its own consumption, or into the bunkers of tugs, ferry-boats, or other steam water-craft.

496. How much coal will an ocean steamer carry in her bunkers?

One of the larger ocean steamers will take from 2000 tons to 3000 tons of bituminous coal to fill her bunkers. In consuming this coal about 100 furnaces are used for the boilers. These boilers frequently have a capacity of 30,000 horse-power.

497. How is an ocean steamer "bunkered" in American ports?

Boats or flat barges of from 200 to 350 tons' capacity are towed alongside the steamer, and then, by means of booms and tackle operated by a small donkey-engine, steel buckets are lowered to the barge, filled with coal, and hoisted to the port-holes. Through these the coal is passed to the ship's bunkers. Sometimes self-discharging steam barges are used, which convey the coal up an incline, and thence through chutes in the steamer's ports by endless carriers or conveyers.

498. How are steamers "bunkered" in the West Indies?

In the West Indies steamers are coaled by negro women, who carry on their heads baskets of coal containing about 100 pounds each.

CHAPTER FIFTEEN

HEAT.

499. What is heat?

This question has never received any satisfactory answer, but it was most generally believed to be a substance of itself, and identical with light. During the 18th century the supposed principle of heat or inflammability was called phlogiston; later this principle was called caloric. To-day heat is called Energy, not matter, and depends upon motion.

500. What is the usual effect produced on bodies by heat?

It causes them to expand, or to occupy more space. If the heat be increased, solid bodies will become liquid, and liquid bodies will become aëriform, or rise in vapor.

501. Can all solid bodies be made fluid with sufficient heat?

That is an established principle, and has been proven in nearly all cases by actual trial.

502. What effect is produced by diminishing the heat of a body?

Bodies so treated lose in bulk, or are condensed, and if the process be continued aëriform bodies become fluid, and fluid bodies become solid; thus, cold changes the vapor into dew or rain, and water into ice.

503. Does ice occupy less space than water?

No; in the act of freezing, water expands. This is caused by the particles of water crystallizing separately, leaving many intervals or hollow spaces between them.

504. To what degree of heat may water be raised?

In an open vessel it may be raised to 212 degrees and no higher. A continued increase of heat has no other effect than to convert the water into steam, which will be of the same degree of heat,—212 degrees.

505. To what degree of heat may steam be raised in a close vessel?

In a close vessel the temperature of steam may be raised to any extent, and is only limited by the strength of the vessel containing it.

506. When, by the application of heat, a solid body is being reduced to liquid, will the temperature continue to rise?

At a certain point in the process the temperature as marked by the thermometer becomes stationary, and although the heat be continually applied, no rise in the temperature will be observed until the whole of the solid has become liquid.

507. What is the "point of liquefaction," or "fusing point"?

The point at which a body begins to fuse or melt; it is different in different substances.

508. What is meant by "latent heat"?

The quantity of heat absorbed by the body in melting and unaccounted for, as far as the thermometer is concerned, is called latent heat.

509. Give an example of latent heat.

If, for example, a quantity of snow at the temperature of zero, with a thermometer in it, be placed in a vessel on the fire, the temperature will be observed to rise to 32 degrees; the snow will then immediately begin to be converted into water, and the thermometer will remain stationary at 32 degrees until the whole of the snow is melted. But

if the same heat be applied to a vessel containing water only, it is soon heated to a high degree and is made to boil.

510. What then becomes of all the heat which is applied to the vessel containing snow, which neither increases the heat of the snow or water?

It is all absorbed or rendered insensible in the conversion of the solid body into a liquid; and the heat so absorbed or rendered latent during the process, being that which is necessary to produce liquefaction, is hence called also the "heat of liquefaction," and amounts to no less than 140 degrees,—that is, although snow or ice may be of the same temperature as water, yet the water actually contains 140 degrees of heat more than the solid snow or ice.

511. What happens after the snow is melted?

As soon as the whole of the snow is melted, the temperature of the water will begin to rise, and will continue to do so until it reaches 212 degrees, when the boiling point of water has been attained and it becomes vapor.

512. Then water cannot be heated beyond the boiling point?

It may be so, if the water be contained in a close vessel, from which the steam can have no escape;

but while steam is rapidly escaping, the water remains at 212 degrees, and the steam at 212 degrees also.

513. What is the amount of heat absorbed?

The heat which is absorbed, called the "heat of vaporization," being that which is required to maintain water in the state of vapor or steam, amounts to no less than 1000 degrees of temperature,—that is, although water may be at 212 degrees and steam may be at 212 degrees, yet the steam contains a larger amount of heat than water, such as is represented by 1000 degrees on the scale of the thermometer.

514. How is the force or pressure of steam measured?

The pressure of steam is measured by the force it exerts on one square inch of surface. At 212 degrees of temperature the pressure of steam is equal to one atmosphere, or 15 pounds on every square inch of surface; at 250 degrees the steam pressure is equal to two atmospheres, or 30 pounds on the square inch; at 275 degrees the pressure is that of three atmospheres, or 45 pounds on the square inch, and so on. This is called the "absolute steam pressure."

515. What is the "effective steam pressure"?

The atmosphere exerts a pressure of 15 pounds per square inch of surface. For effective energy this amount must first be overcome. Steam, therefore, at 212 degrees would just balance the atmosphere and have no effective pressure. If, besides this, the steam would raise a weight of 15 pounds, then its absolute pressure would be 30 pounds, and its effective pressure would be 15 pounds.

516. How is the pressure of steam measured in stationary and locomotive engines?

In general the pressure of steam in stationary and locomotive engines is measured by its "effective steam pressure." The pressure of the atmosphere is not considered in graduating the gauges.

517. How is heat communicated from one part of a body to another?

If it be a solid body, it is communicated from one particle to that next in contact, and so on.

518. How is this illustrated?

This may be illustrated by putting the end of a poker in the fire, and observing how the heat gradually extends from the part which is in the fire to the other end.

519. How is heat communicated to fluids?

If it be from above, the heat is communicated slowly from one particle to another; but if from below, there is a constant internal motion, the heated particles rising to the surface and the colder coming to the bottom, until the whole is raised to the boiling point.

520. Are all bodies good conductors of heat?

No; there is a great difference. Porous bodies having large vacuities, such as cork, cloth, bran, and straw, are bad conductors of heat.

521. What is a unit of heat?

A unit of heat is the quantity of heat required to raise the temperature of one pound of water from 39 degrees to 40 degrees Fahrenheit.

522. What is the mechanical equivalent of a unit of heat?

The mechanical equivalent of a unit of heat is 772 foot-pounds.

523. What is a foot-pound?

A foot-pound, or the unit of work, is the energy exerted in raising or lifting one pound in weight one foot high in one minute.

524. What is meant by a "horse-power"?

A horse-power is equal to 33,000 pounds in weight raised or lifted one foot high in one minute.

525. What working energy is contained in one pound of coal?

A pound of coal contains 14,500 units of heat. The working energy is equal, therefore, to the product of 14,500 units of heat multiplied by 772 foot-pounds, or 11,194,000 pounds in weight raised one foot high in one minute. This amount of work cannot, however, be obtained in practice.

526. What is fire?

According to old writers, fire is one of the four primary conditions of matter, or an elementary substance which has the property of devouring other bodies, the other three elements being air, earth, and water. In the ordinary sense, fire is understood to mean matter in a state of combustion.

527. What is combustion?

By combustion is meant the phenomenon called burning. In coal it is a union of the elements constituting the fuel with the oxygen of the air.

528. How is it produced?

By the application of heat, originating in the following general divisions:

1st. The sun.
2d. Lightning, electricity.
3d. Chemical combinations.
4th. Friction or collision.

529. How is energy produced by combustion?

When coal is heated to the point of ignition, the oxygen of the air unites with the carbon and hydrogen in the coal, and the result is combustion. It is nothing more than a chemical change, producing energy in the form of heat; a piece of iron slowly rusting is undergoing a similar change.

530. What are the ordinary combustibles used in producing heat?

Ordinary combustibles include coal, wood, charcoal, natural gas, oil, coke, and turf.

531. How do these rate in efficiency?

Wood is the least efficient of the combustibles, on account of the great amount of water it contains

that must be converted into steam, while coal is the most efficient. Dry wood, when burned, evolves, on an average, 3600 heat units, and bituminous coal an average of 7500 heat units.

532. What is the cause of spontaneous combustion of coal?

The cause has never been fully understood. In general it may be said to be caused by:

1st. The continuous application of a moderate heat to a large, closely packed coal-pile, such as the heat caused by the proximity of steam-pipes or hot-air flues, or the heat of the sun in summer. Coal in small quantities and in a cool place never ignites spontaneously.

2d. The decomposition of iron pyrites contained in the coal, and its oxidation when exposed to the action of oxygen and moisture.

3d. The absorption by the coal of the oxygen in the air, after it has been mined and broken into fragments above ground. The absorption of the oxygen raises the temperature of the coal, perhaps not sufficiently high to cause combustion, but the oxygen becoming chemically active in the centre of a coal-pile, a sufficient amount of air may be supplied to cause spontaneous combustion.

533. Are low-grade or poor coals more likely to ignite spontaneously than the high-grade coals?

It has not been so proved from the various instances of spontaneous combustion investigated. From them it appears that by far the greater number happened in coals free from iron pyrites and comparatively free from slate, and known as thoroughly high-grade coals.

CHAPTER SIXTEEN

POWER.

534. What is steam?

Steam is water changed by heat into a gas. If we heat water to a temperature of 212 degrees, we produce steam, which escapes in the bubbles of the process called "boiling."

535. Is steam visible?

It is not. The cloud which can be seen escaping from an engine or locomotive consists of small particles of water or vapor, and is the result of condensation of the steam in contact with the colder atmosphere.

536. How is power produced by steam?

By expansion.

537. What is meant by steam expansion?

In all gases a repulsion is exerted between the particles, so that any gas, however small in quantity, will always fill the vessel in which it is held. Steam possesses this same property, and if placed in any vessel, the particles in endeavoring to sep-

arate from each other will exert a force on all its sides. This force is called steam pressure.

538. How is this pressure utilized?

In mechanical contrivances called steam engines, where the steam is admitted to an enclosed cylinder, and by its expansive force is made to move a piston back and forth, and with it the connected machinery.

539. How much water will a pound of coal evaporate in ordinary practice?

The quantity of water which is converted into steam by a pound of coal varies with the quality of the coal and the construction and condition of the boiler. It will average from 6 to 8 pounds of water for each pound of coal.

540. In an ordinary locomotive, how much coal is burned per hour?

For an ordinary locomotive, say of 30 tons weight, it is necessary to burn from 500 to 2000 pounds of coal per hour to generate the required amount of steam and to evaporate from 6000 to 12,000 pounds of water.

541. How far will a ton of coal run a locomotive?

Circumstances will make a great variation in this calculation, but a rough average run, by an ordi-

nary locomotive, would be from 35 to 50 miles with 1 ton of good bituminous coal?

542. Which is the best coal for steaming?

Circumstances again will cause a wide variation in the steaming power of coals. For small boilers, where the fire-box is small and the draft poor or natural, a white-ash coal, high in carbon and low in volatile gases, will give the best results. For larger boilers, with plenty of grate-surface and a draft good or artificial, a coal lower in carbon and higher in volatile matter can be used with more economy, as the combustion will not be so rapid, owing to the greater "body" in the coal.

543. What is meant by the "body" of coal?

Body is the term generally used to indicate the fatty, inflammable property in coals, which is the basis of the phenomenon called combustion. A coal having no body is said to be "dry" or "flashy," owing to its rapid combustion.

544. What is the difference between bituminous and semi-bituminous coals?

When a coal contains as much as 18 per cent. of volatile matter, it is called semi-bituminous, and when the volatile matter is as high as 30 per cent. or over, it is called bituminous, although there is

no bitumen in the composition of either. The oily matter which sometimes exudes from burning coal closely resembles that substance, but it is not bitumen.

545. What is bitumen?

Bitumen is a mineral pitch in various degrees of density from naphtha to asphalt.

546. What is the "mother" of coal?

In examining a piece of bright coal it sometimes occurs that the fragment contains thin layers of a dull black substance, which the observer almost invariably pronounces slate. More frequently this substance is the "mother" of coal, is often as highly combustible as charcoal, and its presence generally indicates a high-grade coal.

547. How can the "mother" be distinguished from slate?

It can generally be distinguished from slate by scraping with the point of a knife. Slate is hard and gritty; the "mother" is soft and woody.

548. Theoretically, what kind of coal would be the most powerful "steamer"?

Theoretically, anthracite would be as much better than the bituminous coal as it exceeds that fuel in

fixed carbon. But this is not the case. Either from the difficulty of combustion or the inefficiency of the mechanical appliances at present in use for generating steam, the excess of carbon in anthracite is not utilized, and, generally speaking, a ton of bituminous coal will generate as much, if not more, steam as an equal ton of anthracite.

549. When was coal first used for locomotive fuel in the United States?

Fifty years ago wood was the fuel in general use for locomotives in the United States. In 1849 only a small proportion of the locomotives on the Reading Railway were burning anthracite coal. On the Baltimore and Ohio Railroad anthracite coal had been used on the very earliest of their locomotives, but these had vertical boilers, and when attempts were made to use anthracite on locomotives with horizontal boilers various obstacles had to be met and overcome.

550. What objections were raised to coal as locomotive fuel?

It was claimed by experts that a coal fire produced destructive effects upon the inside sheets of the fire-box, blistering and burning them away. It was also said to occasion the melting of the grate-bars and the destruction of the boiler-tubes, to-

gether with the accumulation and igniting of fine coal in the smoke-box.

551. How much coal is now burned annually by locomotives in the United States?

The locomotive or "supply" coal now used annually in the United States amounts to about 30,000,000 tons, and is the largest single item of expense in the operation of our railways.

552. What is the cost of locomotive coal?

The cost of coal consumed by a locomotive has been estimated to average about 5 cents per mile of run.

553. Which is the best fuel for locomotives?

On this subject there is much diversity of opinion. There is no doubt that bituminous is the most economical, owing to its extremely low cost and its more easy and perfect combustion. A bituminous coal fire is easily managed by a fireman, and if the better grades are used there is very little waste from ashes or clinkers. An anthracite fire requires much care, burns with a fierce heat, and generates more ashes and clinkers. Its cost is from 20 to 30 per cent. higher,—sufficient to class it as a luxury suitable only for passenger trains, where the smoke from the bituminous coal might be an objectionable

feature. No such objection exists for freight locomotives, and the use of bituminous coal for this purpose is almost universal.

554. Which is the best fuel for steamships?

Bituminous coal is considered the best, being used almost exclusively on all ocean steamers plying between our ports and all parts of the world.

555. Is the consumption of anthracite coal greater than that of bituminous coal in the United States?

In but 10 States of the Union is the consum-p tion of anthracite coal greater than that of bituminous. In half of these the consumption of both coals is nearly equal, anthracite being slightly ahead. In every other State the consumption of bituminous coal is far greater than that of anthracite.

556. What is the proper method of firing a boiler with coal?

If anthracite coal is used, it should be spread evenly over the entire grate in a thin layer, of sufficient thickness, however, to prevent the strong blast from lifting the coal off the grates. If bituminous is used, this system can also be applied for the poorer grades, but if a good non-clinkering coal is supplied it is better first to wet the coal

slightly and then bank it in the back part of the furnace, partially filling the doorway and sloping down towards the front of the grate, where the layer of coal is thin and in an active state of incandescence. This bank of coal is then pushed forward over the burning coals and a new charge is banked at the door as before.

557. What thickness of coal should be in the layer?

The mass of coal in combustion should never exceed 8 inches in thickness, and in most cases 6 inches will be sufficient. Any excess over this amount is waste.

558. What is "smokeless" coal?

There is no such fuel known. All coals in combustion produce more or less smoke, but the quantity thrown off burning coals can in a measure be regulated by the supply of air admitted to the fire. A free admission of air over the fire will produce active combustion of the smoke and gases in all bituminous coals, and in many cases renders them practically, but not entirely, smokeless. The prevention of smoke is the result of good firing, and experience will determine the amount of air which can advantageously be admitted above the fire surface.

CHAPTER SEVENTEEN

METALLURGICAL.

559. When was coal first used for smelting iron in furnaces?

Probably about 1740, in the Colebrookdale Works, in Shropshire, in England, where iron was smelted with charred pit-coal, or coke.

560. What cause first led to the use of coal for smelting iron?

Coal was first used for metallurgical purposes not of choice, but of necessity. The time had arrived in the British iron trade when the enormous amount of wood required for the iron furnaces was not procurable. The grown timber had not only been generally wasted, but there had been an unthrifty neglect in not planting young trees, so that there was a great scarcity of wood not only for industrial purposes, but also for domestic use.

561. Which coal was first used in the United States for smelting iron?

A few attempts were made to use coke made from bituminous coals, but anthracite was the first

to be largely used in American blast furnaces; and for many years after its adaptability to the smelting of iron ore was established it was in greater demand for this purpose than bituminous coal, coked or uncoked.

562. Is this the case at present?

No. In recent years the relative popularity of anthracite and bituminous coals for blast-furnace use has been exactly reversed.

563. What difficulties prevented the immediate introduction of anthracite into American furnaces?

The natural difficulties in the way of the successful introduction of anthracite coal in our blast furnaces were increased by the fact that up to that time, when we began our experiments in its use, no other country had succeeded in using it as a furnace fuel.

564. Had any other attempts been made?

Extensive experiments in smelting with anthracite coal were made in 1828 at Vizille, on the borders of France and Switzerland. Here the attempt was made to use anthracite coal in a blast furnace, either alone or in connection with other fuel.

565. With what results?

It was found that as long as the proportion of anthracite did not exceed one-fifth of the whole fuel, the furnaces continued to work as usual and the iron remained gray; but beyond this limit the pig became white, the furnace chilled, and was in danger of choking. The experiments were abandoned in despair of rendering by this means the manufacture of iron profitable, and the outlay of one or two hundred thousand francs was set down to the debtor side of profit and loss.

566. What caused these failures?

Principally the inferior quality of anthracite coal used, and also the fact that the hot blast for furnaces was not then known.

567. What is a "hot blast"?

The hot blast is one of the important improvements of modern iron-making, by which a great economy of fuel is effected. A great variety of ovens for heating the furnace blast have been invented, but their essential principle is the same. It consists in passing the air through tubes or passages of iron or fire-clay that are heated by a flame or hot air surrounding them. The heat is usually obtained by utilizing the waste inflammable gases

that formerly blazed away from the top of the blast furnace.

568. How do we obtain ordinary malleable iron from pig-iron?

In order to obtain ordinary malleable iron from pig-iron, we remove the bulk of the impurities contained in the pig by a process known as "puddling," and hammering or squeezing.

569. How did the old iron-masters accomplish this?

The old iron-masters simply melted the crude iron in a refining furnace, or "finery," and then subjected it to the action of a blast, which sufficiently oxidized the silicon and carbon.

570. What is silicon?

Silicon is a non-metallic chemical element, and is the base of silex, or silica, which is one of the principal earths. The principal kinds of stone of which silex is the chief component part are quartz, sandstone or freestone, sand flint, rock crystal, granite, agate, and many precious stones. It is used for forming mortar, porcelain, and is melted to form glass.

571. Relate some of the earlier attempts to use anthracite for smelting iron in the United States?

One of the earliest attempts to use anthracite for smelting iron was made at Mauch Chunk, Pennsylvania, in 1819, by the Lehigh Coal and Navigation Company, but was abandoned. In 1825 the smelting of iron by either anthracite or bituminous coals or coke was practically unknown in the United States. In three years, from 1838 to 1841, eleven anthracite furnaces were built in this country.

572. Where were they located?

The eleven anthracite furnaces were located at Mauch Chunk, Phœnixville, Catasauqua, Danville, and Shamokin, in Pennsylvania, and at Stanhope, in New Jersey.

573. What was the capacity of these furnaces?

The total annual production of pig-iron from the eleven anthracite furnaces in operation at that time could not have exceeded 20,000 tons.

574. How many anthracite furnaces are now in the United States?

In 1898 the State of Pennsylvania has 90 anthracite furnaces, New York has 15, and New Jersey has 12, a total of 117.

575. What is their capacity?

The total annual production of pig-iron from the anthracite furnaces now in operation is about 3,200,000 tons.

576. Relate some of the earlier attempts to use bituminous coal in American furnaces.

The first bituminous furnace built in the United States was at Bear Creek, in Armstrong County, Pennsylvania. This was in 1819. It was not successful. After two or three tons of coke iron had been made, the furnace chilled. It was then put in operation with charcoal. In 1835 a good quality of iron was made in the Mary Ann Furnace in Huntingdon County, Pennsylvania, with coke made from Broad Top coal. This was probably the first successful effort made in this country to use bituminous coal in blast furnaces.

During the years 1835–36 blast furnaces were erected at Karthaus and Farrandsville, on the West Branch of the Susquehanna River, in Pennsylvania, for the manufacture of iron by coke, but both were unsuccessful. In 1839 a coke furnace was in operation at Lonaconing, in Maryland, making 10 tons of pig-iron daily, and burning the coke from 50 tons of coal. Near Frostburg, in Maryland, were two large furnaces on the Welsh plan for using coke or bituminous coal.

577. What encouragement was offered American iron-workers?

In 1835 the Franklin Institute, of Philadelphia, offered a gold medal to the person who manufactured in the United States the greatest quantity of iron from the ore during that year, using no other fuel than bituminous coal or coke, the quantity to be not less than 20 tons. In 1836 the Pennsylvania Legislature passed an act for the encouragement of the manufacture of iron by mineral fuel.

578. Did these efforts exert an appreciable influence on the manufacture of iron?

Scarcely any. Many experiments were made with coke and bituminous coal for blast-furnace use, but they were generally attended with loss. In 1849 there was not one coke furnace in blast in the United States.

579. When did the results indicate the successful use of coke in American furnaces?

In 1856 there were 21 blast furnaces in Pennsylvania and 3 in Maryland which were using coke, or were adapted to its use, and their total production in that year was over 44,000 tons of pig-iron. After 1856 the use of this fuel in the blast furnaces increased in Pennsylvania and was extended to

other States, but it was not until after 1865 that its use for this purpose increased rapidly, amounting during that year to 100,000 tons, in 1880 to over 2,000,000 tons, and in 1890 to over 10,000,000 tons.

580. How many bituminous and coke furnaces are now in the United States?

There are now 256 blast furnaces in this country using bituminous coal and coke.

581. Where are they located?

Of the bituminous and coke furnaces in the United States, 76 are in Pennsylvania, 53 in Ohio, 39 in Alabama, 24 in Virginia, 17 in Illinois, 12 in Tennessee, 6 in Kentucky, 5 in Maryland, 4 each in West Virginia and Wisconsin, 3 each in New York, Missouri, and Colorado, 2 each in North Carolina, Georgia, and Indiana, and 1 in Minnesota.

582. What is their capacity?

The total annual production of pig-iron from the bituminous furnaces now in operation is over 13,000,000 tons, or over four times as much as the combined product of all the anthracite furnaces in the United States.

CHAPTER EIGHTEEN

GAS.

583. What is gas?

Gas is a term we apply to all aëriform, invisible, elastic fluids. The air we breathe is composed of two gases, oxygen and nitrogen. The term is generally used to describe a mixture of particular gases for illuminating purposes.

584. How is gas produced?

Gas is sometimes produced naturally, as those gases issuing from decayed vegetable or animal matter, or those issuing from volcanoes and the atmosphere; others are produced by chemical manipulation, as in the process called destructive distillation.

585. What is destructive distillation?

Destructive distillation is the process of heating an organic compound in a closed vessel, without access of air, and collecting the products.

586. What substances will produce illuminating gas by the process of destructive distillation?

By distilling fats, oils, wood, peats, bones, resins, wax, tallow, or any animal or vegetable substance,

gas is expelled and the original nature of the material is destroyed. By submitting coal to this process, gas, such as used for lighting, is produced.

587. Why is coal almost universally employed for this purpose?

Coal is almost universally employed for this purpose on account of its price, the facility with which it is distilled, and the quantity and quality of the coke derived therefrom after the gas is expelled. Formerly the production of gas from resins, fats, and oils was common, but, on account of the greater cost of the gas produced as compared with that obtained from coal, such processes have been abandoned.

588. Give a simple demonstration of the manufacture of coal gas?

If we put some powdered coal into the bowl of a common clay pipe, plaster over the opening with clay, and then insert the bowl in a fire, allowing the stem to project from between the grate-bars, we will have commenced the process of destructive distillation. In a few minutes a stream of gas will issue from the stem. On applying a light it will burn with a bright flame, and we have made coal gas on a small scale.

589. How is it made on a large scale?

In a gas-works the tobacco-pipe bowl is replaced by large cast-iron or earthen vessels, called retorts; these are embedded in ovens, and exposed to the action of a furnace, and so kept continually red-hot; they are partially filled with coal and hermetically closed, when the heat decomposes the coal and expels the gas, which passes from the retorts through several vessels for condensing the vapors in combination and extracting impurities. When the gas is purified it passes to the gasometer, ready for distribution.

590. By this process how much gas can be obtained from a ton of gas coal?

In this way a ton of good gas coal will yield about 10,000 cubic feet of illuminating gas; but a vast improvement on this process is obtained by taking the coal used in the first operation, which has now become coke, heating it to incandescence, and forcing steam through the mass.

591. How much gas would thus be produced?

By this means about 30,000 more feet of gas are obtained from the ton of coal, not including such coal as is used for the fires producing the heat.

592. What is this gas called?

The gas produced by this process, in which steam is used, is called water gas, since it is the decomposition of the water that releases the hydrogen forming the gas. Carbon, when highly heated, has so much affinity for oxygen that it will decompose steam in order to combine with the oxygen that forms a part of the steam. This is the principle that makes water gas possible. Either anthracite coal or coke may be used to secure the necessary carbon.

593. How is the brilliancy of this gas increased?

A vapor made from crude oil is commonly added in small quantities to give greater illuminating power to water gas.

594. What is gas coal?

All bituminous coal will produce gas, but, generally speaking, the gas coals of the United States are those containing from 30 to 40 per cent. of volatile matters,—that is, hydrogen, nitrogen, and oxygen. The excess of hydrogen in these coals renders them particularly suitable for the production of carburetted hydrogen, or, as it is commonly called, "gas." Hence the term now commonly used, "gas coals."

595. Who first used coal for destructive distillation?

Coal was first submitted to destructive distillation by a German named Johann Joachim Becher, in the year 1680. He secured a "patent for a new way of making pitch and tarre out of pit-coale never before found or used by any other."

596. When was illuminating gas first obtained from coal?

Gas was first obtained from coal by Dr. Hales in 1726, who, filling a bladder with it, and puncturing a small hole therein, lighted the issuing gas. This, however, was merely a scientific experiment.

597. When was coal gas first used for lighting purposes?

The discoverer of the practical application of coal gas for lighting purposes was Murdock, a Scotchman, who in 1792 first lighted his house and offices with it.

598. When was the first gas company chartered?

The first gas company in the world for the production of gas as an article of commerce was chartered in London in 1813, under the title of "The Gaslight and Coke Company."

599. Was the introduction of coal gas attended with any difficulties?

The opposition against the introduction of coal gas was violent in the extreme. Great men, scientists, and authors spoke and wrote against it. Such men as Napoleon, Sir Walter Scott, and Sir Humphrey Davy thought the scheme of lighting dwellings with gas a reckless and foolish one, and it took great perseverance and courage to overcome the existing prejudice against its use. The public, however, soon became reconciled to it, and in 1814 London was first lighted with gas made from coal.

600. Was water gas known in those days?

Not commercially, but a gas of similar properties was obtained by causing steam to pass through a tube filled with red-hot charcoal.

601. When was the first attempt made to introduce gas into the United States?

The first attempt to introduce gas into this country was made at Baltimore in 1816. The company first organized, which is the oldest in this country, constructed works for the manufacture of tar gas, but was unsuccessful, and it was not until about 1821 that gas was successfully introduced in Baltimore.

602. What other attempts were made?

Boston next introduced it in 1822, and continues to work under its first charter. New York followed, commencing operations in 1823, but did not get into successful operation until 1827. Philadelphia introduced coal gas in 1835.

603. What gas coals were used at this time in the United States?

Up to 1842 the Virginia coals, mined in the neighborhood of Richmond, and imported English coals were the principal gas coals used in this country, and until 1850 constituted the chief supply to the gas-works of Philadelphia and other American cities. About six years later the gas coals of Western Pennsylvania began to be used in Philadelphia, to the practical exclusion of both the foreign and the Virginia coals.

604. Where are the principal beds of gas coal in the United States?

The principal beds of gas coal in the United States are in the country adjacent to Pittsburg, Pennsylvania, and southeasterly across the line in West Virginia.

605. When were these coals first used for gas-making?

The Pittsburg gas coals were first brought to market over the lines of the Pennsylvania Railroad about 1856. These were followed later by the shipments of Youghiogheny gas coals and West Virginia gas coals eastward over the Baltimore and Ohio Railroad to tide-water, and thence by vessels to the various coast cities.

606. Did these first attempts at gas-making with American coals meet with any opposition?

The prejudice then existing against these coals was so formidable that it seemed impossible to overcome. The famous Newcastle coals of England and the Pictou Provincial coals were considered by gas experts to be the only coals suitable for gas-making, and it was only after repeated trials and experiments that the American product was recognized as equal in every way to the best English coals, and superior to the Provincial. To-day the Pennsylvania and West Virginia gas coals are the standards of excellence as gas producers of the world.

607. What is cannel coal?

Cannel coal is supposed to be the product of vegetable matter,—as other coals,—but of fine

particles of vegetation mixed with carbon and deposited in small lakes or lagoons. It generally occurs in "pockets," and yields a very high percentage of volatile matter, and also ash. It is frequently used in gas-making as an enricher.

608. In the distillation of gas coal, what component parts are collected?

The bituminous part is melted out in the form of tar. There is disengaged at the same time a large quantity of aqueous fluid, contaminated with a portion of oil and various ammoniacal salts. A large quantity of carburetted hydrogen and other inflammable gases make their appearance, and the fixed base of the coal remains behind in the retorts in the form of a carbonaceous substance called coke.

609. How much coke remains from a ton of distilled gas coal?

The amount varies with different coals, ranging from 1500 to 1700 pounds for each gross ton of coal used.

CHAPTER NINETEEN

COKE.

610. What is charcoal?

Charcoal is coal made by charring wood. Formerly charcoal was the name for charred sea-coal or mineral coal, and the word is popularly used for the carbonaceous residue of vegetable, animal, or mineral substances when they have undergone smothered combustion.

611. What is meant by "smothered combustion"?

Wood consists of carbon, hydrogen, and oxygen, the last two being in the proportion to form water. When wood is heated in the open air it burns completely away, with the exception of a small white ash; but if the supply of air be limited, then the combustion is "smothered," and only the more volatile matters burn away, while most of the carbon remains in the form of wood-charcoal.

612. Supposing that this process be applied to bituminous coal, what would be the result?

Bituminous coal consists also of carbon, hydrogen, and oxygen. When it is heated in the open

air it burns completely away, leaving but a small quantity of ash; but if we limit the amount of air, as in a coke-oven, during combustion, then only the volatile gases are consumed, while a large proportion of the carbon remains in the form of coke.

613. What, then, is coke?

Coke is a form of fuel obtained by the heating of bituminous coal in confined spaces, whereby its more volatile constituents are consumed or burned away.

614. How is the process of coking in mounds conducted?

Coking is done either in heaps, or mounds, or in coke-ovens. If done in mounds, the coal is piled up in round stacks around a wide open chimney or column, the lumps in the centre, and the slack or fine coal outside, the whole being covered with wet coke dust, except at certain air-holes. The mound is ignited at the top, and burns gradually down and outward, giving off at first much smoke and vapor. When the fire ceases to be smoky, the process of coking is concluded, all openings are covered over to exclude air and extinguish combustion, and the cooling of the mound is done by drenching it with water; these mounds used to be called "fires."

615. How does this differ from the process of making coke in ovens?

The principle of making coke in coke-ovens is the same, but the process is much quicker and more economical, and the resulting coke is better in quality than that made in mounds.

616. When was the process of coke-making first known?

The process of coke-making is very old. As early as 2000 years ago coke was an article of commerce in the Chinese province of Hunan.

617. What is known of early efforts in coking coal?

A patent was issued as early as 1557 in Germany for a process that was called the "desulphurizing of coal." In 1590 a license was issued for cleaning coal and freeing it from its disagreeable smell, and further patents followed in 1620 and 1627 for smelting iron with coke, and rendering coal as useful and agreeable as charcoal for domestic purposes. Again, a further patent was issued in 1633 to several parties for "charking" coal and smelting iron.

618. What is meant by "charking"?

The verb "chark" means "to burn to a black cinder," whereas the meaning of "char" was de-

fined to be "to burn wood to a black cinder." Coal thus prepared was called "coak," and wood so heated was called "charcoal."

619. When was coke first made in ovens?

In 1769 the fact was announced by one of the technical writers that coke was made in England, "not only in piles, but in closed furnaces." A short time afterwards the iron-masters of Liege adopted with success that system of coking. At the same time coking in ovens was carried on in the villages around London, the coke being prepared for the use of malsters and for other purposes. In 1781 the application of coke for the smelting of iron had become general in England, and coke-ovens were in operation at Newcastle-on-Tyne and at Cambridge.

620. What are the constituent parts of coke?

The constituent parts of coke are principally carbon and ash, the latter being the inorganic matter of the coal. An analysis of coke would show about 90 per cent. of fixed carbon and the balance of ash.

621. What is the position of coke as a fuel?

The excess of carbon in coke ranks it as capable of great heating power, and the small amount of

combustible gases renders it slow to ignite and free from smoke during combustion.

622. What are the impurities in coke?

The impurities in coke are the sulphur and phosphorus which it may contain.

623. Describe the general appearance of coke.

In external appearance coke may be light gray and bright, or, as it is generally termed, "silvery," or of a metallic lustre, or it may be dull and black, or iridescent. It is generally rough-surfaced, but sometimes, especially that portion of a charge near oven walls, is smooth and glossy, like polished graphite. Sometimes hair-like threads are found clinging to the larger lumps.

624. Describe the physical structure of coke.

In its physical structure coke may be porous and light, or compact, dense, and heavy. It may be hard and capable of sustaining a high crushing and compressive strain or load, or it may be soft and brittle, with a low crushing point and compressive strength. Its "ring" or sound when struck is in some samples almost metallic, and in others it is dull and heavy. Its degree of combustibility and ease of ignition, also, are variable.

625. What do we mean by "dense" and "hard" coke?

All coke is more or less cellular in its structure. The less the cell space the denser the coke, the greater the cell space the more porous,—that is, "dense" and "porous" are opposite conditions. "Hard" is a term properly applied to the cell walls of the coke, and coke is "hard" or "soft" as the cell walls are hard or soft. Coke may therefore be dense and not hard,—that is, its cell space may be small and the cell walls weak; or it may be porous and hard,—that is, its cell space may be large and the cell walls hard and strong.

626. What is the typical coke for blast-furnace use?

Physically the typical coke for blast-furnace use should be bright, silvery, hard, and porous, with a metallic ring.

627. Does a chemical analysis indicate the value of coke?

Not always. An analysis of coke may show a very high percentage of carbon and very low of ash and impurities; but if the coke is soft and brittle its value as a furnace fuel is very small; whereas a coke lower in carbon and higher in ash, if it is physically a hard coke, or one with hard

cell walls, would be much superior to the one in which the cell walls are brittle and weak.

628. When was coke first made in the United States?

The manufacture of coke in the United States is of very recent date, the census of 1850 showing a total amount in value of only $15,000. Prior to this small quantities of coke were made for smelting iron in Pennsylvania.

629. Relate the process of coke-making in the United States?

In 1870 the manufacture of coke in Ohio was begun, and in 1880 coke was manufactured in Alabama, Colorado, Georgia, Illinois, Indiana, Ohio, Pennsylvania, Tennessee, and West Virginia, 9 States in all.

630. From what coal seams is most of the coal taken for coking in the United States?

By far the largest part of the coal used for coking in the United States comes from 3 coal seams,—the Pittsburg seam in Pennsylvania, the Pottsville conglomerate in the New River and Flat Top districts of Virginia and West Virginia, and the Pratt seam of Alabama.

631. From what coal is Connellsville coke made?

The coal used in making Connellsville coke is from the Pittsburg seam, locally known as the "Connellsville" seam. The run-of-mine coal is put directly into the ovens, of the form known as the "bee-hive" pattern, without any preparation or screening, and is converted into coke.

632. Describe the process of charging the coal in bee-hive ovens?

The coal is brought to the ovens in iron cars called "larries," which discharge their contents through a circular opening in the tops of the ovens by means of chutes attached to the larries. This is called "charging" the ovens, and a charge is about 6 tons of coal. A coke-oven has two openings,—the circular opening in the top or crown, and another in the side, called the door. After charging, the door is bricked up and plastered with clay, leaving a small opening at the top of the bricks.

633. How is combustion first produced in the ovens?

When coke-ovens are first "lighted," fires are made in them of wood, and afterwards of coal or coke. These fires are merely preliminary, and are made to heat the ovens. When they have been sufficiently heated the fires are drawn and the

ovens carefully cleaned of ashes. The charges of coking coal are now put in the ovens, and soon ignite from the heat retained from the previous fires, the distillation of the gases begins, and these gases pass off through the holes in the tops of the ovens.

634. How is the coke drawn from the ovens?

The coal is allowed to burn in the ovens for 48 hours, at the end of which time it is thoroughly coked; this is ascertained by looking into the oven over the top of the door. A man then tears away the brick door and, inserting the nozzle of a hose, drenches the heated mass with water until it is quenched. The coke is then allowed to stand until the water is all driven off as vapor, after which it is drawn out on the ground by laborers using long iron scrapers. From the ground the coke is forked into the railroad cars and shipped to its destination.

635. How is combustion in the ovens continued?

The heat retained in an oven from the previous charge, together with that obtained from the alternate ovens which are in blast,—the coke being drawn from every other oven,—is sufficient to continue combustion after each charge is made.

636. What method is pursued in charging coke-ovens?

An oven charged, say on Monday, would be ready to draw on Wednesday; an oven charged on Tuesday would be drawn on Thursday, etc.

637. What is meant by "72-hour" coke?

Owing to the suspension of labor on Sunday, an oven charged on Friday must necessarily go over to Monday, so that all charges made on Friday and drawn on Monday must of necessity be in the ovens 72 hours, and the coke resulting is called 72-hour coke.

638. Is "72-hour" coke better than "48-hour" coke?

All other conditions being equal, 72-hour coke does not differ from 48-hour coke, either in analysis or physical structure. A Friday oven is always charged with an increased amount of coal, which necessitates longer burning; the resultant coke is therefore no better than the coke from the smaller charges of the other days in the week. When the gases have been expelled from the coal the ovens are sealed, with a lid over the top opening, and no additional burning will improve the quality of the coke.

639. How does the charge of coal burn in a coke-oven?

The charge of coal begins to burn and coke from the top downward, as in charcoal or coke piles in the open air. Should sufficient air be admitted to the ovens, the coal would be consumed to ashes.

640. What are "black ends" in coke?

Black ends are caused by cold oven floors or insufficient burning, whereby the process of coking is arrested before that part of the coal is converted which rests upon the floor of the oven. Black ends should not be confused with "smoked ends," the latter being simply a discoloration of the coke with smoke, which in no way impairs its quality.

641. What is "crushed" coke?

Coke which is broken and screened into various sizes, like anthracite coal, for domestic use is called crushed coke. One ton of coke so prepared is equal in bulk to about 2 tons of anthracite. Owing to its freedom from gas and clinkers, together with its large percentage of heat units, crushed coke is a typical domestic fuel.

642. What is the difference between "furnace" and "foundry" coke?

There is no essential difference, both coming from the same ovens, and frequently from the same

charges. Operators, however, make a difference in the price for their trouble and labor in selecting coke for foundry use, sometimes having it hand-picked for that purpose.

643. What is the annual coke production of the United States?

At present coke is made in 21 States of the Union at the rate of about 14,000,000 tons annually from about 46,000 ovens.

CHAPTER TWENTY

BY-PRODUCTS.

644. What is meant by the word "by-product"?

A by-product is a secondary or additional product,—something produced, as in a manufacturing process, in addition to the principal product.

645. What are the by-products of coke?

In the coking process the by-products which are frequently collected and utilized are the gas, tar, and ammonia.

646. How are these by-products collected?

These by-products are collected by burning the coal in a peculiar kind of coke-oven other than the bee-hive pattern. These special ovens are called "flue ovens."

647. What is the principle of a flue oven?

The essential principle of a flue or retort oven is the cooking of the coal in retorts or air-tight chambers, as in a gas-works. The coal in the ordinary bee-hive oven is burned from the inside, while

that in a flue oven is burned from gas on the outside.

648. Describe the construction of flue ovens?

The Semet-Solvay flue ovens are constructed in a rectangular form, the retorts being above the foundations of the ovens. The ovens are charged at the top by larries, and the coal is burned 24 hours, or one-half the time required by the common bee-hive ovens. On each side of the ovens are 3 horizontal flues, running the entire length and containing gas, which heats the ovens. The flues are made of tile, and are not more than 2 inches thick, so that the heat can easily be conveyed through.

649. How are the ovens operated?

The gas in the horizontal flues that are used to heat the ovens is taken from the other ovens that have been burned; 1 oven is drawn every 2 hours, and the waste heat is saved in boilers, which are placed between 2 rows of ovens. The gas from the ovens goes to the by-product house, and is there washed and scrubbed and the by-products obtained. In every ton of coal there is estimated to be 10,000 cubic feet of gas; of this amount 7000 feet are used for heating the ovens

and the remainder is saved and used for fuel or illuminating purposes.

650. How is the coke drawn from the ovens?

These ovens can be opened at both ends, and the coke pushed out by an engine running along the end of the ovens. The coke thus forced out is drenched with water and cooled as in the bee-hive process.

651. How does the cost of a flue oven compare with the bee-hive?

The cost of the flue oven is three or four times that of the bee-hive oven, but it is claimed that the increased yield of retort coke as compared with oven coke, together with the value of the by-products obtained, compensates for the difference.

652. What is known of this system of coke-making in the United States?

Comparatively little, as its introduction into this country is of recent date. The continent of Europe, however, has practically abandoned the bee-hive ovens. In Germany, Belgium, and France there are only a few isolated plants of bee-hive ovens in operation. Such, however, is not the case in England, where the bee-hive ovens, as in this country, are in general use.

653. In the production of illuminating gas, what by-products are obtained?

In making illuminating gas from coal we obtain as by-products ammoniacal liquor, tar, and coke.

654. What use can be made of these?

The coke can be used as fuel, while the tar and ammoniacal liquor can by chemical decomposition be used in a great variety of processes of great value and utility.

655. How much tar can be obtained from a ton of coal?

From a ton of coal we get about 110 to 120 pounds of tar.

656. How much watery liquor is thus obtained?

From a ton of coal we get about 20 to 25 gallons of watery liquor.

657. What is obtained from the tar?

Tar furnishes the raw material for the production of a multitude of valuable substances,—coloring matters better than natural dyes; explosives, such as picric acid; perfumes and flavoring materials, like bitter-almond oil and vanillin; sweetening matter, like saccharin; disinfectants, like

carbolic acid; medicines rivalling the natural alkaloids; and developers for photographers, such as hydroquinone and eikonogen.

658. What is paraffin?

Paraffin is a wax-like substance obtained by distillation from highly bituminous cannel coal. It has for years been the principal material employed in the manufacture of candles in Great Britain and Germany, having for that purpose, to a large extent, superseded the use of beeswax, spermaceti, stearic acid, and tallow. It is also used in many branches of the arts and manufactures.

659. How is paraffin produced?

The coal, or bituminous shale, when taken from the mines is broken into small pieces and put into retorts. In the retorts the first chemical process—destructive distillation—takes place. The coal, according to quality, yields from 20 to 40 gallons of crude oil per ton, and over 60 gallons of ammonia water, from which sulphate of ammonia is obtained. The paraffin is obtained by pressing and refrigeration of the oil. It is afterwards refined and then filtered through cloth and filter-paper, and run into pans to solidify into cakes of convenient size for the candle-maker.

660. Where is paraffin chiefly produced?

In Scotland, where some 15 companies with an aggregate capital of about $12,000,000 are engaged in this industry alone. These companies use about 2,000,000 tons of coal per annum, producing about 60,000,000 gallons of crude oil.

661. Is paraffin from coal manufactured in the United States?

The industry was started here, but the discovery of petroleum—essentially the same thing as paraffin oil—rendered the business unprofitable.

662. What is pitch?

Pitch is a thick, black, sticky substance, obtained by boiling down tar.

663. How is it utilized?

When mixed with coal-dust, pitch is used in the manufacture of briquettes for artificial fuel. Pitch is also used in all the applications of asphalt for paving, roofing, and felting.

664. How is sulphate of ammonia obtained from the watery liquor in coal utilized?

Sulphate of ammonia is extensively used in various chemical operations, and is also in good de-

mand as a fertilizer. It adds nitrogen to the soil, and is an excellent agent for stimulating all plant growth.

665. Are tar and ammonia recovered from other than gas-works?

For many years tar and ammonia have been recovered from the coal gases which burned away and were wasted at the tops of the blast furnaces. This is notably the case in Scotland, where nearly all the blast furnaces are equipped to utilize the waste gases,—

1st. Under the boilers of the blowing engines.
2d. In the air-stoves for heating the blast.
3d. In the recovery plant for tar and ammonia.

666. How will coal be used in the future?

The time is not far distant when we will abandon the clumsy, inefficient contrivances for burning coal in our houses and work-shops. The annoyance of black coal-dust, sooty smoke, and grimy ashes will be replaced by the comfort and convenience of fuel gas of high grade and healthful properties. Central plants will deliver this cleanly and convenient product for all purposes of warmth and power.

The impurities and inorganic matter of coal will

first be removed, the noxious vapors scrubbed and purified. Then, hand in hand with its beautiful sister, Electricity, we will introduce into our homes Gas, the pure spirit of Coal.

INDEX

Index

THE END